US009479690B2

(12) **United States Patent**
Nakamaru

(10) **Patent No.: US 9,479,690 B2**
(45) **Date of Patent: Oct. 25, 2016**

(54) **PHOTOGRAPHIC APPARATUS AND METHOD FOR FOCUSING CONTROL USING TWO HIGH PASS FILTERS**

(71) Applicant: **FUJIFILM Corporation**, Tokyo (JP)

(72) Inventor: **Fumio Nakamaru**, Saitama (JP)

(73) Assignee: **FUJIFILM Corporation**, Tokyo (JP)

(*) Notice: Subject to any disclaimer, the term of this patent is extended or adjusted under 35 U.S.C. 154(b) by 0 days.

(21) Appl. No.: **15/010,760**

(22) Filed: **Jan. 29, 2016**

(65) **Prior Publication Data**

US 2016/0150152 A1 May 26, 2016

Related U.S. Application Data

(63) Continuation of application No. PCT/JP2014/069175, filed on Jul. 18, 2014.

(30) **Foreign Application Priority Data**

Aug. 1, 2013 (JP) 2013-160395

(51) **Int. Cl.**
H04N 5/232 (2006.01)
G06K 9/46 (2006.01)
(Continued)

(52) **U.S. Cl.**
CPC ***H04N 5/23212*** (2013.01); ***G02B 7/365*** (2013.01); ***G03B 3/10*** (2013.01);
(Continued)

(58) **Field of Classification Search**
USPC 348/345–357
See application file for complete search history.

(56) **References Cited**

U.S. PATENT DOCUMENTS

2004/0227843 A1* 11/2004 Watanabe H04N 5/23212 348/354
2008/0297648 A1* 12/2008 Furuki G02B 7/38 348/345

(Continued)

FOREIGN PATENT DOCUMENTS

JP 2007-67862 A 3/2007
JP 2009-237327 A 10/2009

(Continued)

OTHER PUBLICATIONS

English translation of Written Opinion of the International Search Authority (Form PCT/ISA/237) dated Oct. 28, 2014, issued in PCT/JP2014/069175.

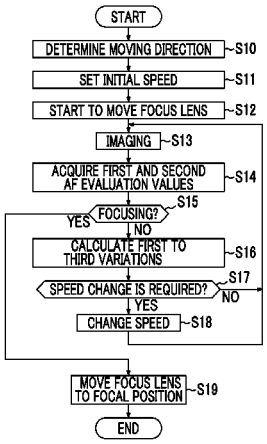
(Continued)

Primary Examiner — Shahbaz Nazrul
(74) *Attorney, Agent, or Firm* — Birch, Stewart, Kolasch & Birch, LLP

(57) **ABSTRACT**

A digital camera is provided with a frequency component extraction unit, an AR evaluation value acquisition unit, a variation calculation unit, and a moving speed control unit. The frequency component extraction unit has first and second filters, and extracts first and second spatial frequency components. The AF evaluation value acquisition unit integrates the first and second spatial frequency components to acquire first and second AF evaluation values. The variation calculation unit calculates a first variation corresponding to first-order differentiation of the first AF evaluation value, a second variation corresponding to first-order differentiation of the second AF evaluation value, and a third variation corresponding to second-order differentiation of the second AF evaluation value. The moving speed control unit controls the moving speed of a focus lens at the time of an AF operation based on the rates of increase or decrease of the first to third variations.

6 Claims, 23 Drawing Sheets



(51) **Int. Cl.**

G02B 7/36	(2006.01)
G03B 3/10	(2006.01)
G03B 13/36	(2006.01)
G06K 9/00	(2006.01)
G06K 9/52	(2006.01)

(52) **U.S. Cl.**

CPC ***G03B 13/36*** (2013.01); ***G06K 9/4661*** (2013.01); *G06K 9/00228* (2013.01); *G06K 9/00684* (2013.01); *G06K 9/522* (2013.01)

(56) **References Cited**

U.S. PATENT DOCUMENTS

2009/0322936	A1*	12/2009	Liaw	H04N 5/23212 348/354
2011/0228053	A1*	9/2011	Aoki	H04N 5/23212 348/49
2011/0249150	A1*	10/2011	Shintani	H04N 5/23212 348/240.3
2011/0261251	A1*	10/2011	Okamoto	G02B 7/102 348/345
2012/0057069	A1	3/2012	Yamasaki	
2014/0293117	A1*	10/2014	Murakami	G02B 21/365 348/349
2015/0092098	A1*	4/2015	Konishi	H04N 5/2352 348/333.11
2015/0215517	A1*	7/2015	Kusaka	G02B 7/282 348/353

FOREIGN PATENT DOCUMENTS

JP	2012-103708 A	5/2012
JP	2014-38291 A	2/2014
WO	WO 2010/050200 A1	5/2010

OTHER PUBLICATIONS

International Search Report for PCT/JP2014/069175 mailed on Oct. 28, 2014.

Written Opinion of the International Searching Authority for PCT/JP2014/069175 mailed on Oct. 28, 2014.

* cited by examiner

FIG. 1

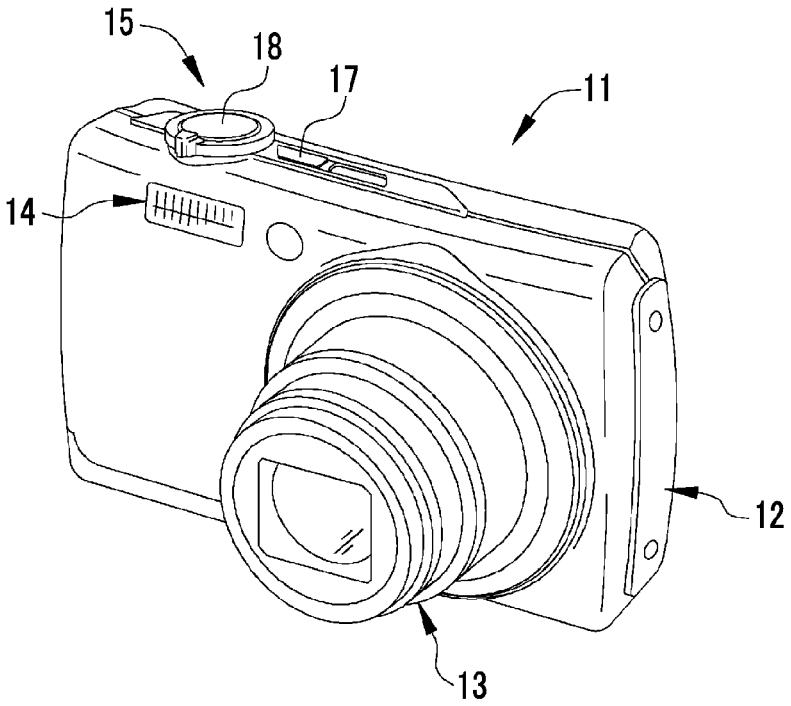


FIG. 2

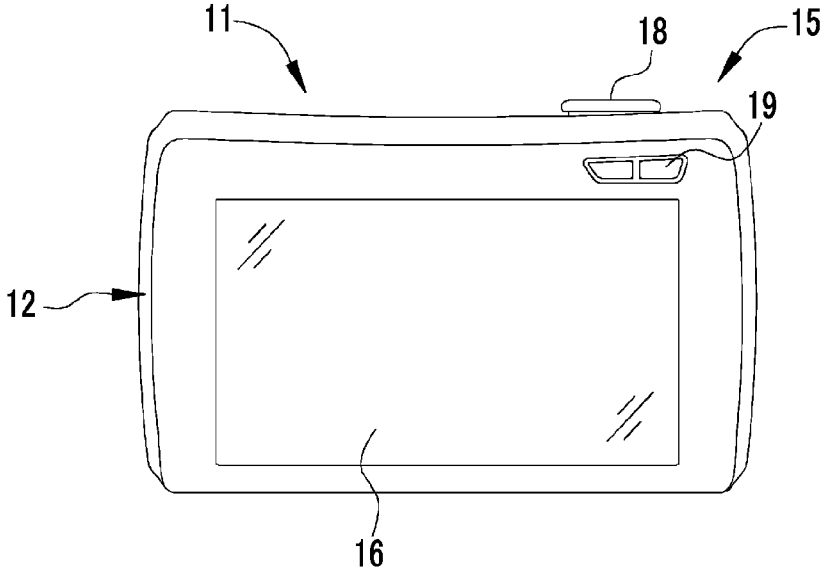


FIG. 3

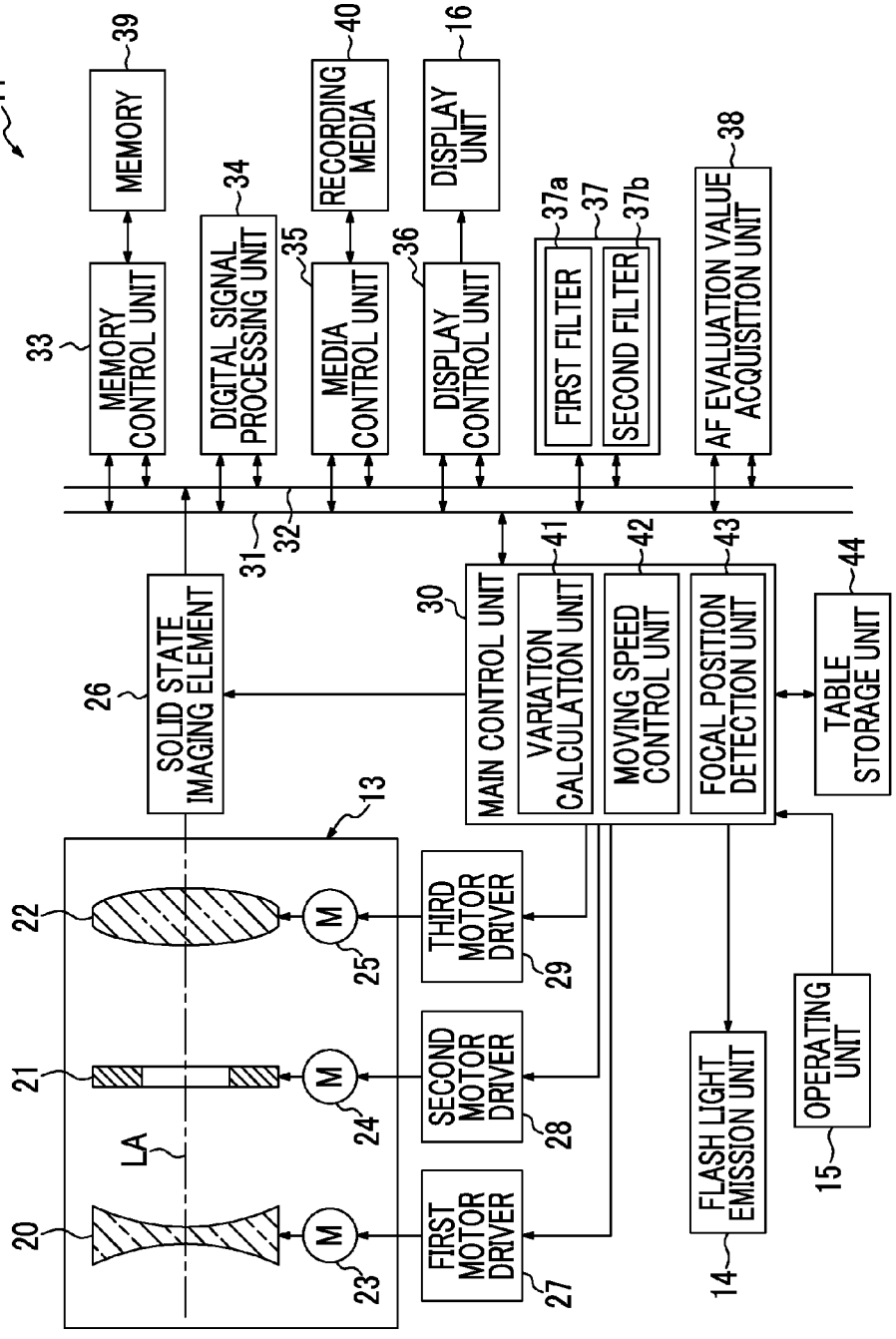

11
MEMORY
39
RECORDING MEDIA
40
DISPLAY UNIT
16
34
37a
37
37b
38
33
MEMORY CONTROL UNIT
DIGITAL SIGNAL PROCESSING UNIT
35
MEDIA CONTROL UNIT
36
DISPLAY CONTROL UNIT
FIRST FILTER
SECOND FILTER
AF EVALUATION VALUE ACQUISITION UNIT
31
32
41
42
43
44
30
MAIN CONTROL UNIT
VARIATION CALCULATION UNIT
MOVING SPEED CONTROL UNIT
FOCAL POSITION DETECTION UNIT
TABLE STORAGE UNIT
26
SOLID STATE IMAGING ELEMENT
13
22
21
20
LA
M
25
24
23
THIRD MOTOR DRIVER
SECOND MOTOR DRIVER
FIRST MOTOR DRIVER
29
28
27
FLASH LIGHT EMISSION UNIT
14
OPERATING UNIT
15

FIG. 4

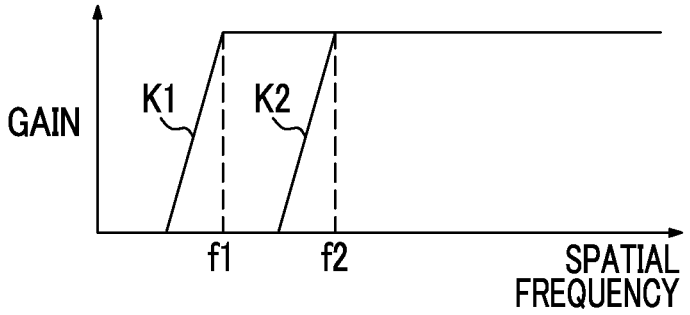


FIG. 5

TB

$RV_1(x)$	$RV_2(x)$	$RV_3(x)$	SPEED SP
0	0	0	H
		+	H
		−	H
	+	0	H
		+	H
		−	M
	−	0	L
		+	L
		−	L
+	0	0	H
		+	H
		−	H
	+	0	H
		+	H
		−	M
	−	0	L
		+	L
		−	L
−	0	0	L
		+	L
		−	L
	+	0	L
		+	L
		−	L
	−	0	L
		+	L
		−	L

FIG. 6

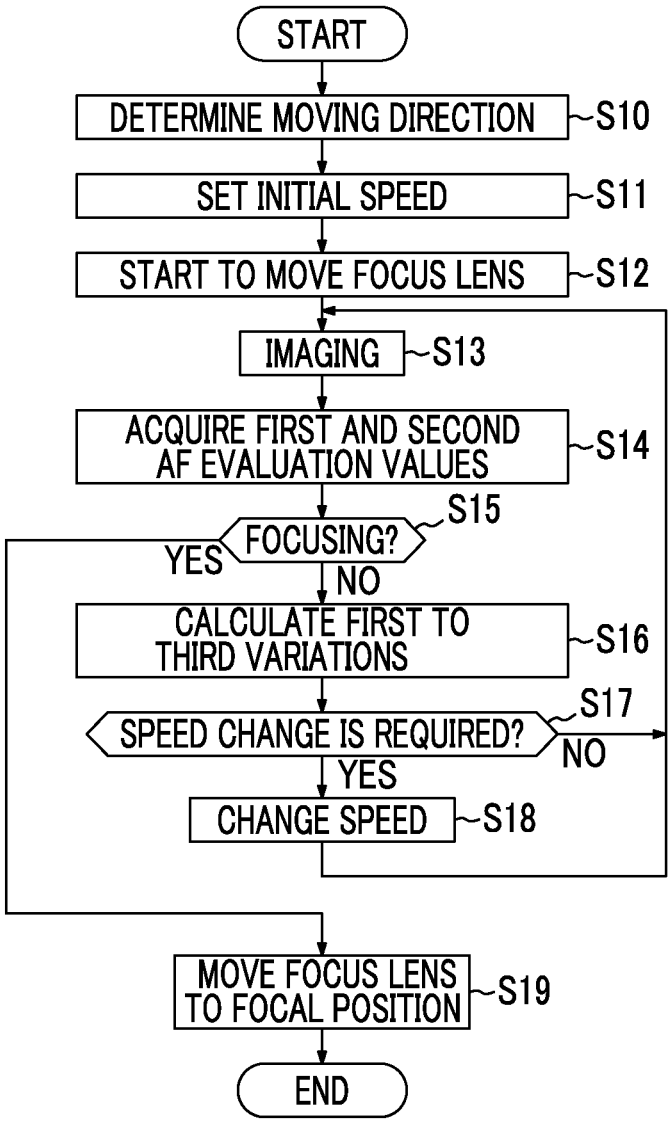

START
DETERMINE MOVING DIRECTION
S10
SET INITIAL SPEED
S11
START TO MOVE FOCUS LENS
S12
IMAGING
S13
ACQUIRE FIRST AND SECOND AF EVALUATION VALUES
S14
FOCUSING?
S15
YES
NO
CALCULATE FIRST TO THIRD VARIATIONS
S16
SPEED CHANGE IS REQUIRED?
S17
NO
YES
CHANGE SPEED
S18
MOVE FOCUS LENS TO FOCAL POSITION
S19
END

FIG. 7

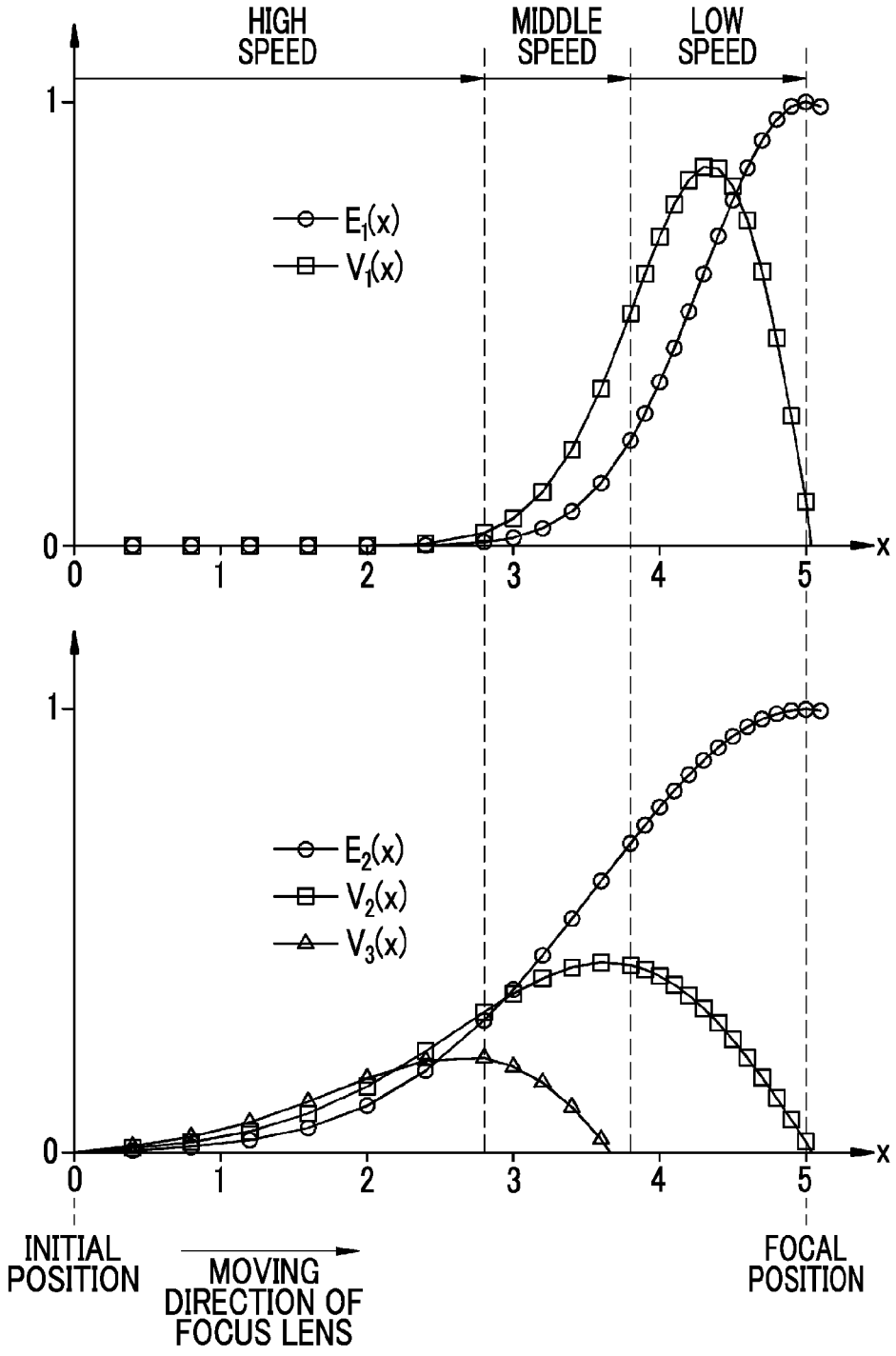

HIGH SPEED
MIDDLE SPEED
LOW SPEED
1
0
$E_1(x)$
$V_1(x)$
x
0 1 2 3 4 5
1
0
$E_2(x)$
$V_2(x)$
$V_3(x)$
x
0 1 2 3 4 5
INITIAL POSITION
MOVING DIRECTION OF FOCUS LENS
FOCAL POSITION

FIG. 8

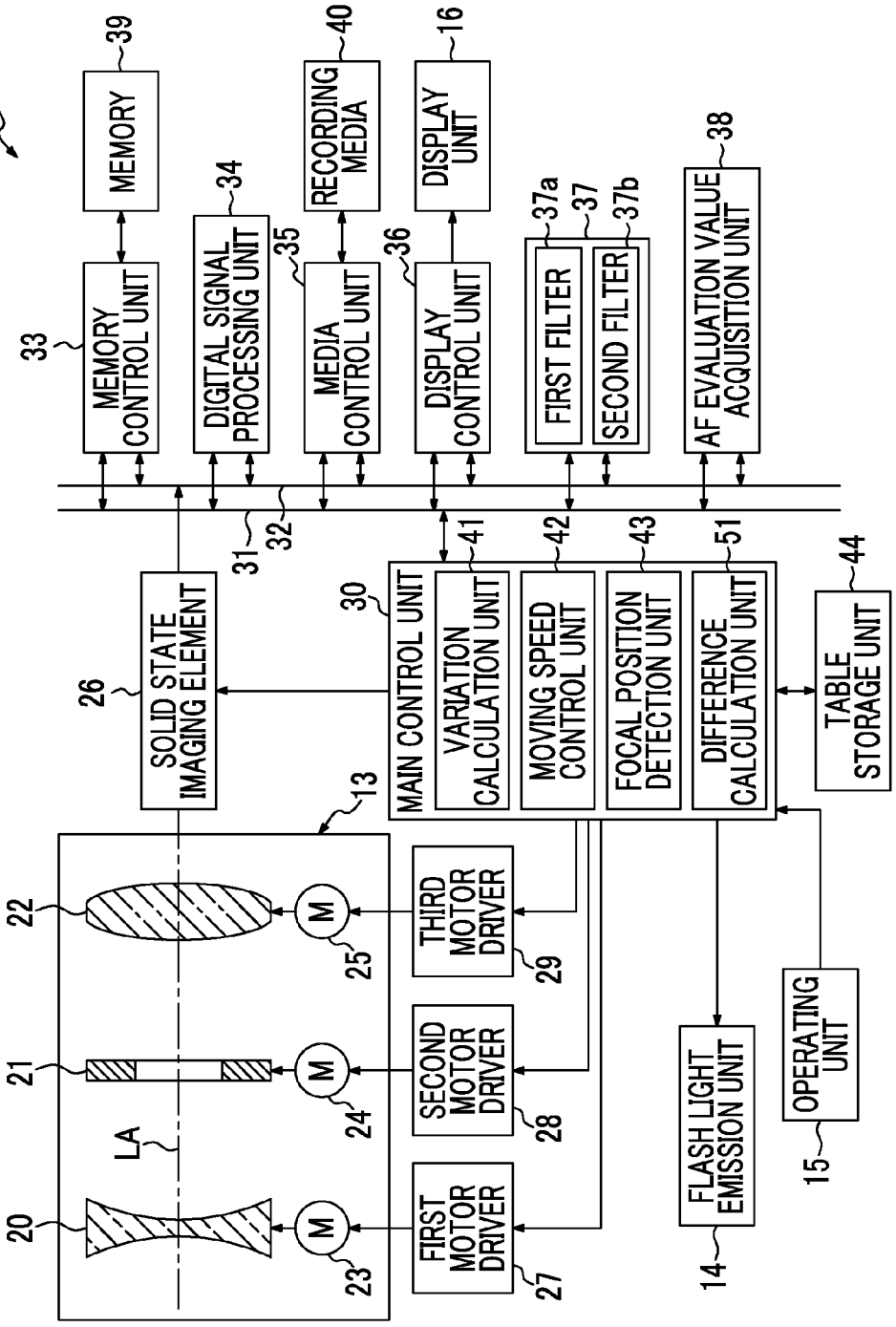

50
MEMORY
39
RECORDING MEDIA
40
DISPLAY UNIT
16
MEMORY CONTROL UNIT
33
DIGITAL SIGNAL PROCESSING UNIT
34
MEDIA CONTROL UNIT
35
DISPLAY CONTROL UNIT
36
FIRST FILTER
37a
SECOND FILTER
37b
37
AF EVALUATION VALUE ACQUISITION UNIT
38
31
32
41
42
43
51
44
SOLID STATE IMAGING ELEMENT
26
MAIN CONTROL UNIT
30
VARIATION CALCULATION UNIT
MOVING SPEED CONTROL UNIT
FOCAL POSITION DETECTION UNIT
DIFFERENCE CALCULATION UNIT
TABLE STORAGE UNIT
13
22
21
20
LA
M
25
24
23
THIRD MOTOR DRIVER
29
SECOND MOTOR DRIVER
28
FIRST MOTOR DRIVER
27
FLASH LIGHT EMISSION UNIT
14
OPERATING UNIT
15

FIG. 9

TB1

$RV_1(x)$	$RV_2(x)$	$RV_3(x)$	SPEED SP
0	0	0	H
		+	H
		−	H
	+	0	H
		+	H
		−	M
	−	0	L
		+	L
		−	L
+	0	0	H
		+	H
		−	H
	+	0	H
		+	H
		−	M
	−	0	L
		+	L
		−	L
−	0	0	L
		+	L
		−	L
	+	0	L
		+	L
		−	L
	−	0	L
		+	L
		−	L

TB2

$RV_1(x)$	$RV_2(x)$	$RV_3(x)$	SPEED SP
0	0	0	H
		+	H
		−	H
	+	0	H
		+	H
		−	M
	−	0	L
		+	L
		−	L
+	0	0	H
		+	H
		−	H
	+	0	M
		+	L
		−	M
	−	0	L
		+	L
		−	L
−	0	0	L
		+	L
		−	L
	+	0	L
		+	L
		−	L
	−	0	L
		+	L
		−	L

FIG. 10

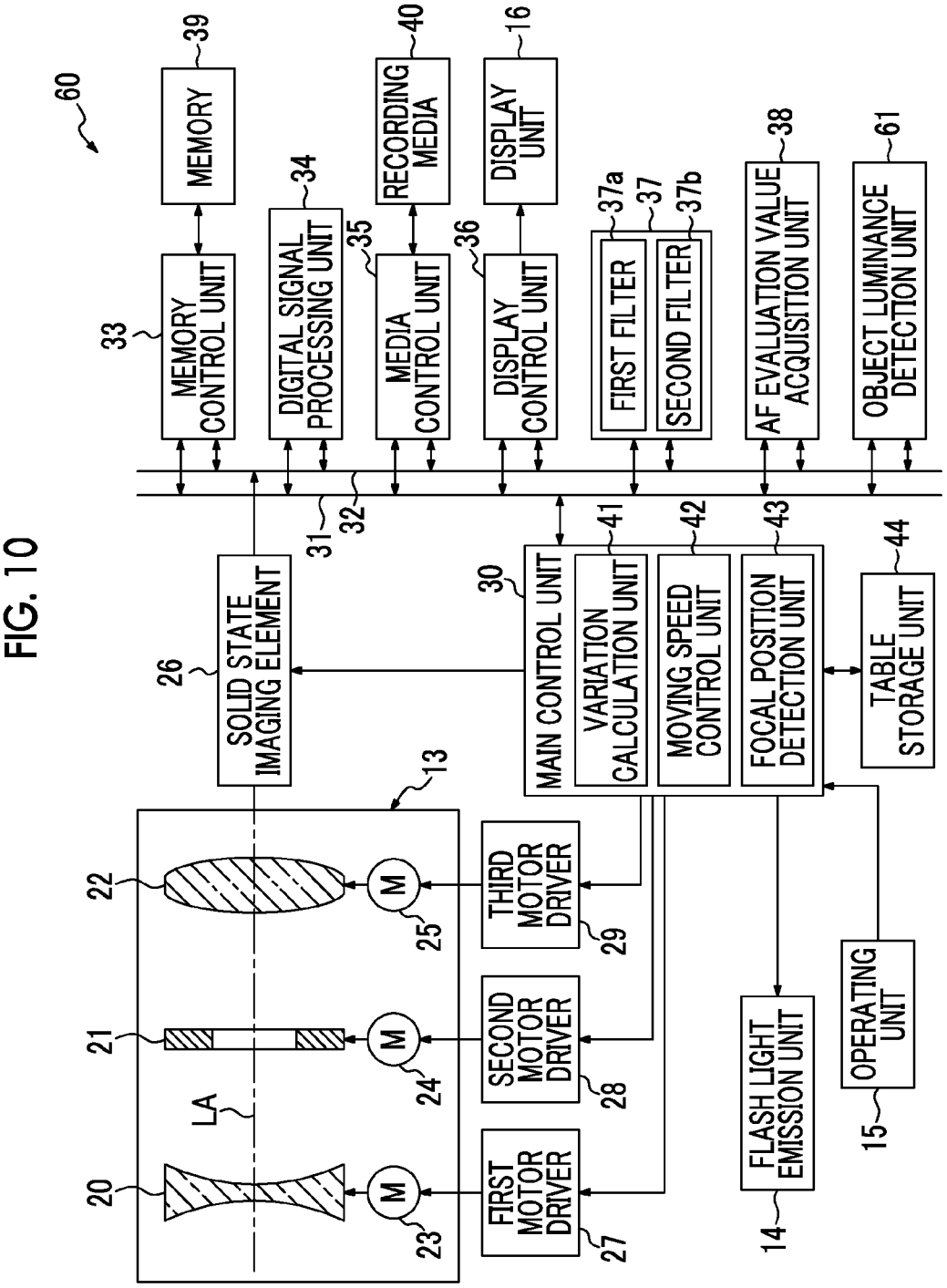

60
MEMORY
39
RECORDING MEDIA
40
DISPLAY UNIT
16
MEMORY CONTROL UNIT
33
DIGITAL SIGNAL PROCESSING UNIT
34
MEDIA CONTROL UNIT
35
DISPLAY CONTROL UNIT
36
FIRST FILTER
37a
SECOND FILTER
37b
37
AF EVALUATION VALUE ACQUISITION UNIT
38
OBJECT LUMINANCE DETECTION UNIT
61
31
32
SOLID STATE IMAGING ELEMENT
26
MAIN CONTROL UNIT
30
VARIATION CALCULATION UNIT
41
MOVING SPEED CONTROL UNIT
42
FOCAL POSITION DETECTION UNIT
43
TABLE STORAGE UNIT
44
13
22
21
20
LA
M
25
24
23
THIRD MOTOR DRIVER
29
SECOND MOTOR DRIVER
28
FIRST MOTOR DRIVER
27
FLASH LIGHT EMISSION UNIT
14
OPERATING UNIT
15

FIG. 11

TB1

$RV_1(x)$	$RV_2(x)$	$RV_3(x)$	SPEED SP
0	0	0	H
		+	H
		−	H
	+	0	H
		+	H
		−	M
	−	0	L
		+	L
		−	L
+	0	0	H
		+	H
		−	H
	+	0	H
		+	H
		−	M
	−	0	L
		+	L
		−	L
−	0	0	L
		+	L
		−	L
	+	0	L
		+	L
		−	L
	−	0	L
		+	L
		−	L

TB2

$RV_1(x)$	$RV_2(x)$	$RV_3(x)$	SPEED SP
0	0	0	H
		+	H
		−	H
	+	0	C
		+	H
		−	M
	−	0	C
		+	C
		−	L
+	0	0	C
		+	C
		−	C
	+	0	C
		+	H
		−	M
	−	0	C
		+	C
		−	L
−	0	0	C
		+	C
		−	L
	+	0	C
		+	C
		−	C
	−	0	L
		+	C
		−	L

FIG. 12

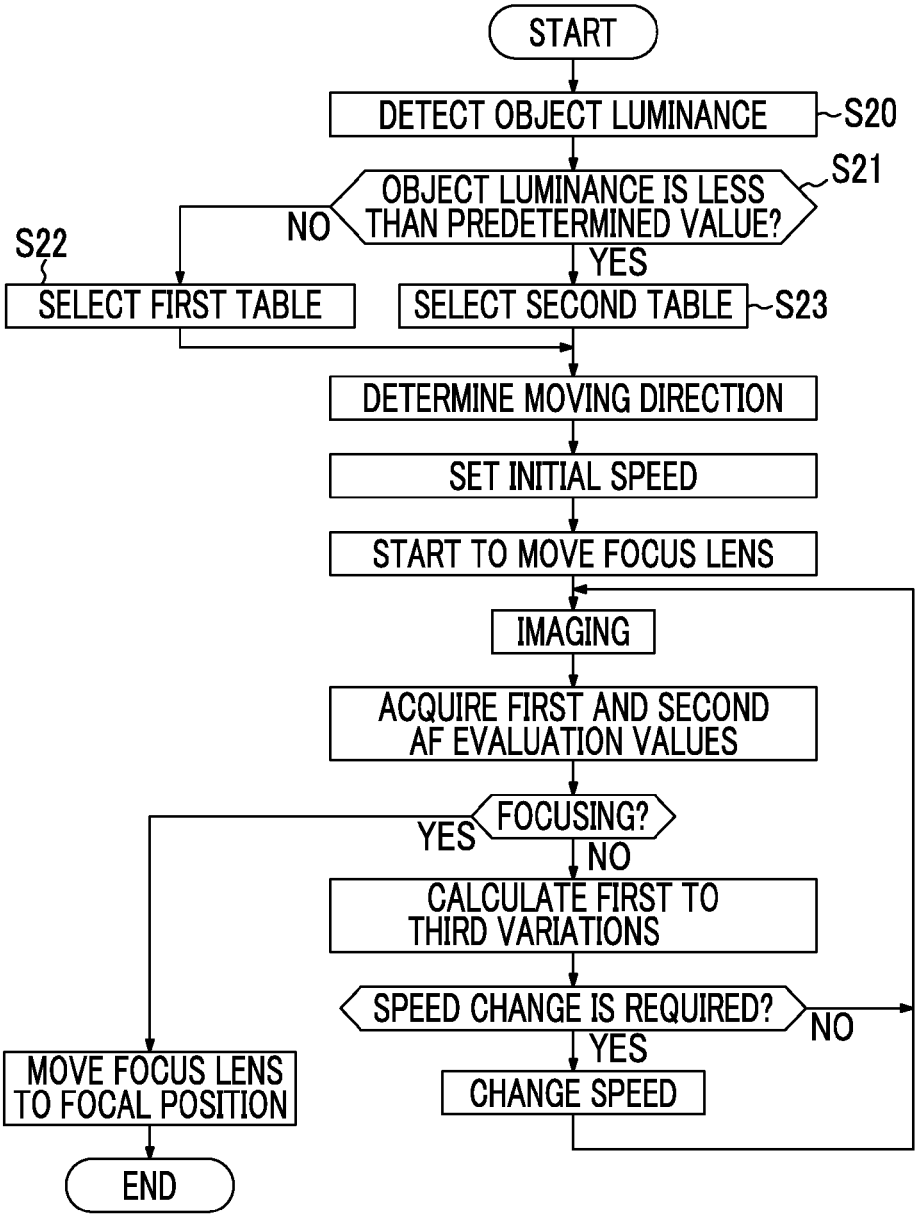

START
DETECT OBJECT LUMINANCE
S20
OBJECT LUMINANCE IS LESS THAN PREDETERMINED VALUE?
S21
NO
YES
S22
SELECT FIRST TABLE
SELECT SECOND TABLE
S23
DETERMINE MOVING DIRECTION
SET INITIAL SPEED
START TO MOVE FOCUS LENS
IMAGING
ACQUIRE FIRST AND SECOND AF EVALUATION VALUES
FOCUSING?
YES
NO
CALCULATE FIRST TO THIRD VARIATIONS
SPEED CHANGE IS REQUIRED?
NO
YES
CHANGE SPEED
MOVE FOCUS LENS TO FOCAL POSITION
END

FIG. 13

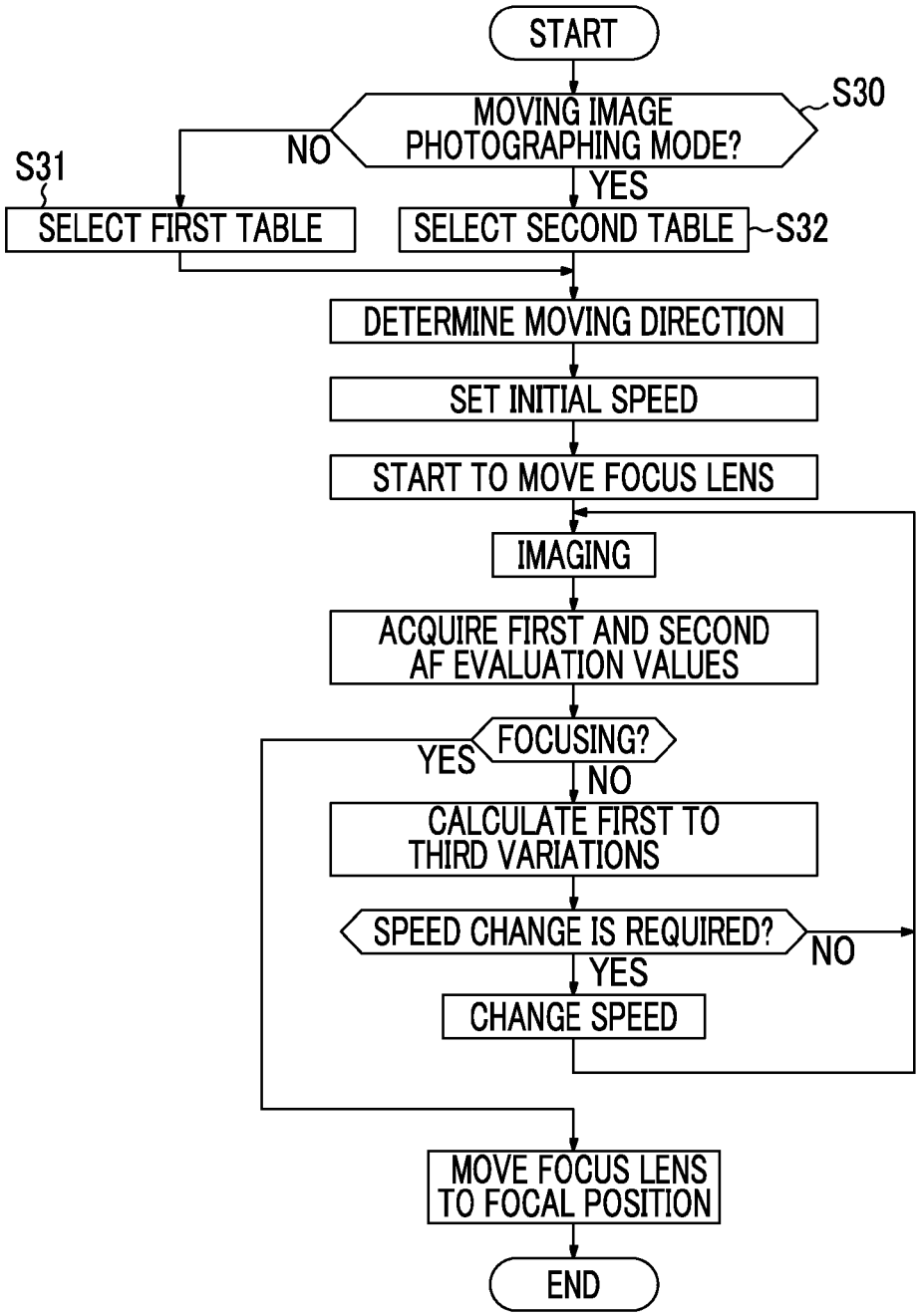

START
MOVING IMAGE PHOTOGRAPHING MODE?
S30
NO
YES
S31
SELECT FIRST TABLE
SELECT SECOND TABLE
S32
DETERMINE MOVING DIRECTION
SET INITIAL SPEED
START TO MOVE FOCUS LENS
IMAGING
ACQUIRE FIRST AND SECOND AF EVALUATION VALUES
FOCUSING?
YES
NO
CALCULATE FIRST TO THIRD VARIATIONS
SPEED CHANGE IS REQUIRED?
NO
YES
CHANGE SPEED
MOVE FOCUS LENS TO FOCAL POSITION
END

FIG. 14

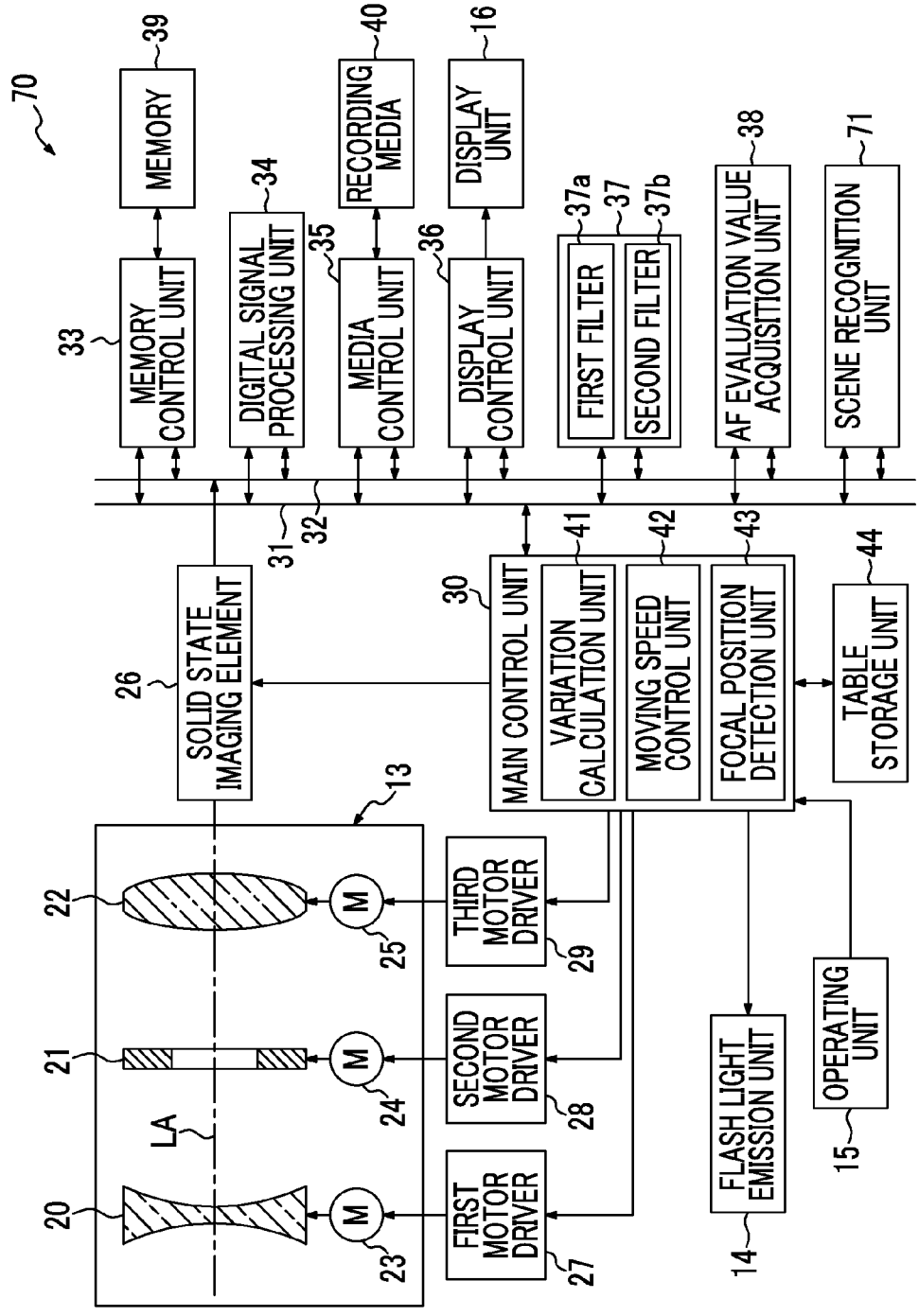

70
MEMORY
39
RECORDING MEDIA
40
DISPLAY UNIT
16
MEMORY CONTROL UNIT
33
DIGITAL SIGNAL PROCESSING UNIT
34
MEDIA CONTROL UNIT
35
DISPLAY CONTROL UNIT
36
FIRST FILTER
37a
SECOND FILTER
37b
37
AF EVALUATION VALUE ACQUISITION UNIT
38
SCENE RECOGNITION UNIT
71
31
32
SOLID STATE IMAGING ELEMENT
26
MAIN CONTROL UNIT
30
VARIATION CALCULATION UNIT
41
MOVING SPEED CONTROL UNIT
42
FOCAL POSITION DETECTION UNIT
43
TABLE STORAGE UNIT
44
13
22
21
20
LA
M
25
24
23
THIRD MOTOR DRIVER
29
SECOND MOTOR DRIVER
28
FIRST MOTOR DRIVER
27
FLASH LIGHT EMISSION UNIT
14
OPERATING UNIT
15

FIG. 15

TB1

$RV_1(x)$	$RV_2(x)$	$RV_3(x)$	SPEED SP
0	0	0	H
		+	H
		−	H
	+	0	H
		+	H
		−	M
	−	0	L
		+	L
		−	L
+	0	0	H
		+	H
		−	H
	+	0	H
		+	H
		−	M
	−	0	L
		+	L
		−	L
−	0	0	L
		+	L
		−	L
	+	0	L
		+	L
		−	L
	−	0	L
		+	L
		−	L

TB2

$RV_1(x)$	$RV_2(x)$	$RV_3(x)$	SPEED SP
0	0	0	H
		+	H
		−	Ⓜ
	+	0	H
		+	H
		−	M
	−	0	L
		+	L
		−	L
+	0	0	M
		+	M
		−	M
	+	0	M
		+	M
		−	L
	−	0	L
		+	L
		−	L
−	0	0	L
		+	L
		−	L
	+	0	L
		+	L
		−	L
	−	0	L
		+	L
		−	L

FIG. 16

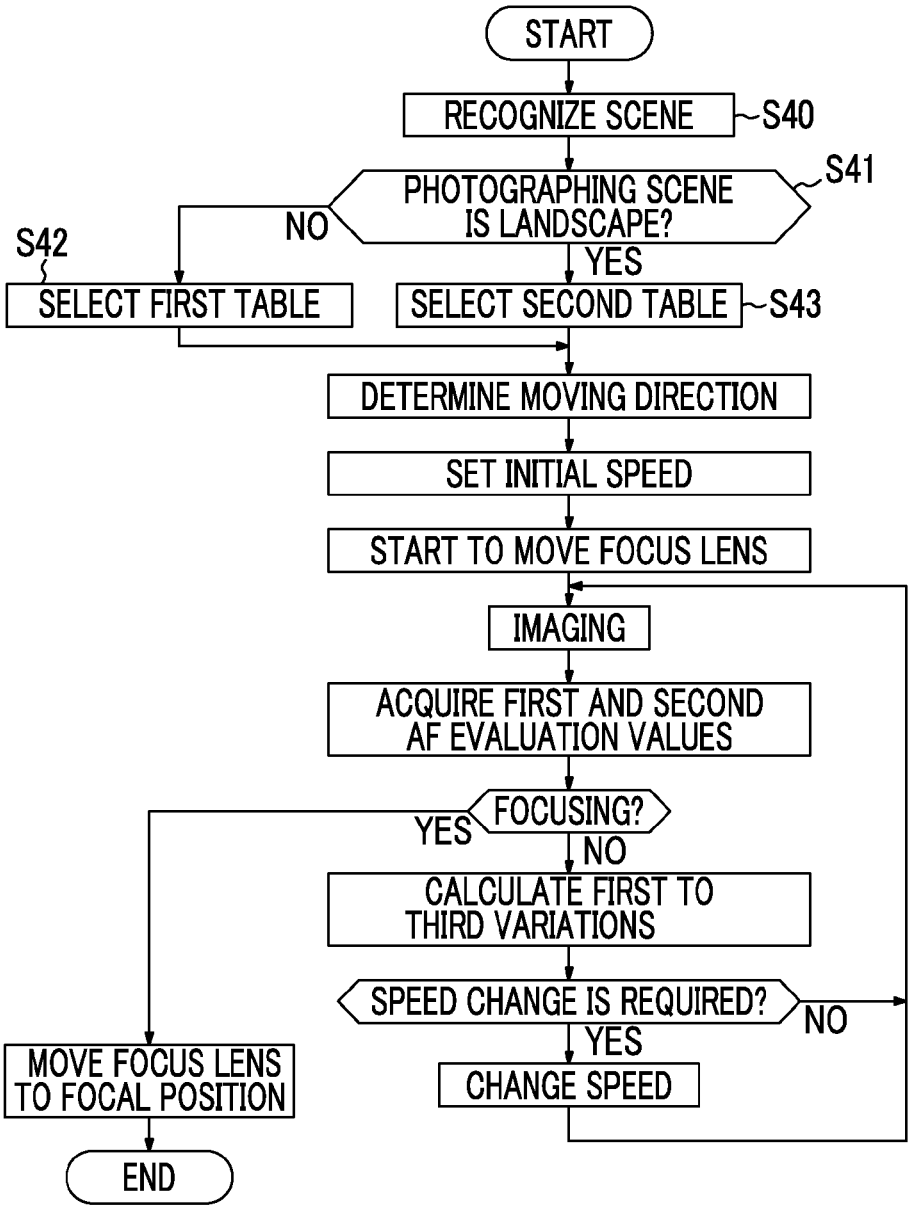

START
RECOGNIZE SCENE
S40
PHOTOGRAPHING SCENE IS LANDSCAPE?
S41
NO
YES
S42
SELECT FIRST TABLE
SELECT SECOND TABLE
S43
DETERMINE MOVING DIRECTION
SET INITIAL SPEED
START TO MOVE FOCUS LENS
IMAGING
ACQUIRE FIRST AND SECOND AF EVALUATION VALUES
FOCUSING?
YES
NO
CALCULATE FIRST TO THIRD VARIATIONS
SPEED CHANGE IS REQUIRED?
NO
YES
CHANGE SPEED
MOVE FOCUS LENS TO FOCAL POSITION
END

FIG. 17

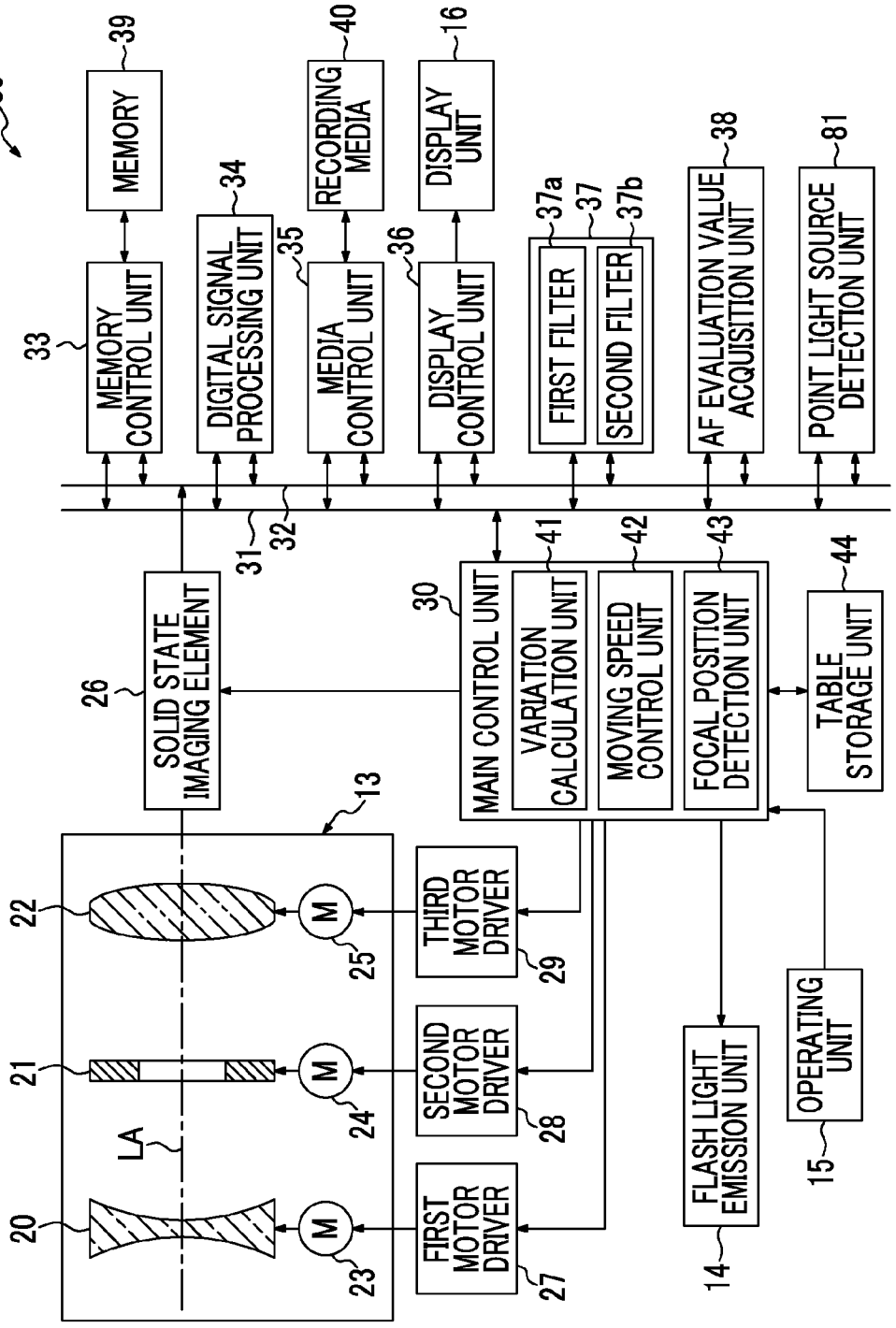

80
MEMORY
39
RECORDING MEDIA
40
DISPLAY UNIT
16
MEMORY CONTROL UNIT
33
DIGITAL SIGNAL PROCESSING UNIT
34
MEDIA CONTROL UNIT
35
DISPLAY CONTROL UNIT
36
FIRST FILTER
37a
SECOND FILTER
37b
37
AF EVALUATION VALUE ACQUISITION UNIT
38
POINT LIGHT SOURCE DETECTION UNIT
81
31
32
SOLID STATE IMAGING ELEMENT
26
MAIN CONTROL UNIT
30
VARIATION CALCULATION UNIT
41
MOVING SPEED CONTROL UNIT
42
FOCAL POSITION DETECTION UNIT
43
TABLE STORAGE UNIT
44
13
22
21
20
LA
M
25
24
23
THIRD MOTOR DRIVER
29
SECOND MOTOR DRIVER
28
FIRST MOTOR DRIVER
27
FLASH LIGHT EMISSION UNIT
14
OPERATING UNIT
15

FIG. 18

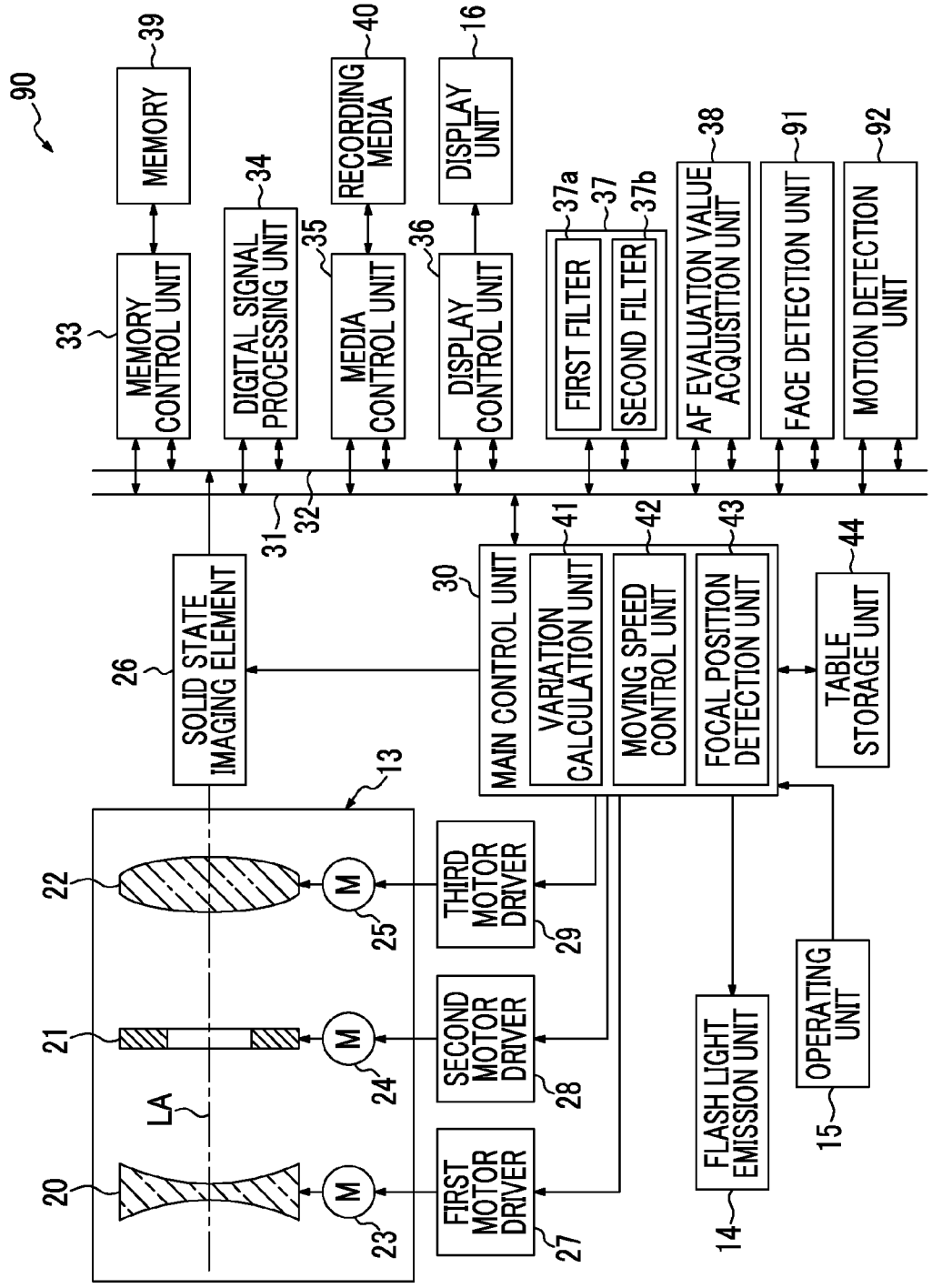

90
MEMORY
39
RECORDING MEDIA
40
DISPLAY UNIT
16
MEMORY CONTROL UNIT
33
DIGITAL SIGNAL PROCESSING UNIT
34
MEDIA CONTROL UNIT
35
DISPLAY CONTROL UNIT
36
FIRST FILTER
37a
SECOND FILTER
37b
37
AF EVALUATION VALUE ACQUISITION UNIT
38
FACE DETECTION UNIT
91
MOTION DETECTION UNIT
92
31
32
SOLID STATE IMAGING ELEMENT
26
MAIN CONTROL UNIT
30
VARIATION CALCULATION UNIT
41
MOVING SPEED CONTROL UNIT
42
FOCAL POSITION DETECTION UNIT
43
TABLE STORAGE UNIT
44
13
22
21
20
LA
M
25
24
23
THIRD MOTOR DRIVER
29
SECOND MOTOR DRIVER
28
FIRST MOTOR DRIVER
27
FLASH LIGHT EMISSION UNIT
14
OPERATING UNIT
15

FIG. 19

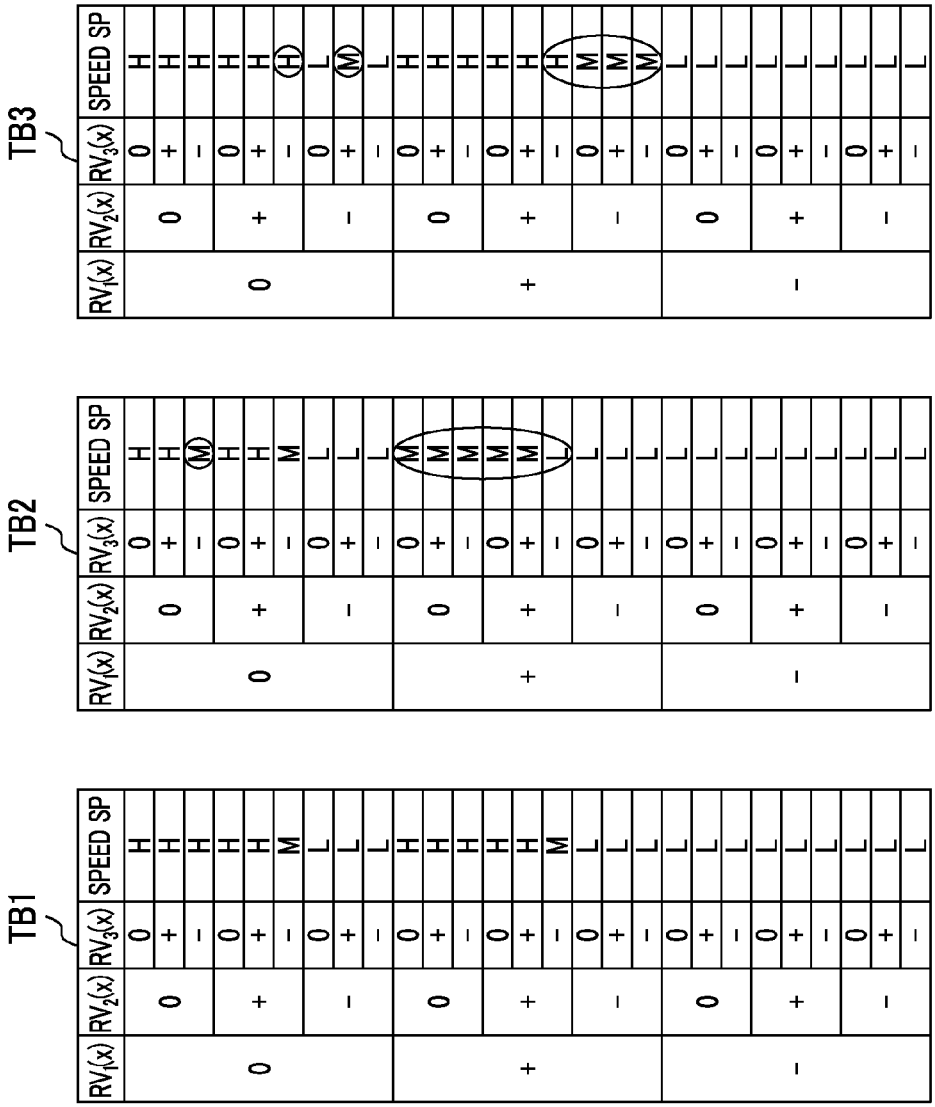


FIG. 20

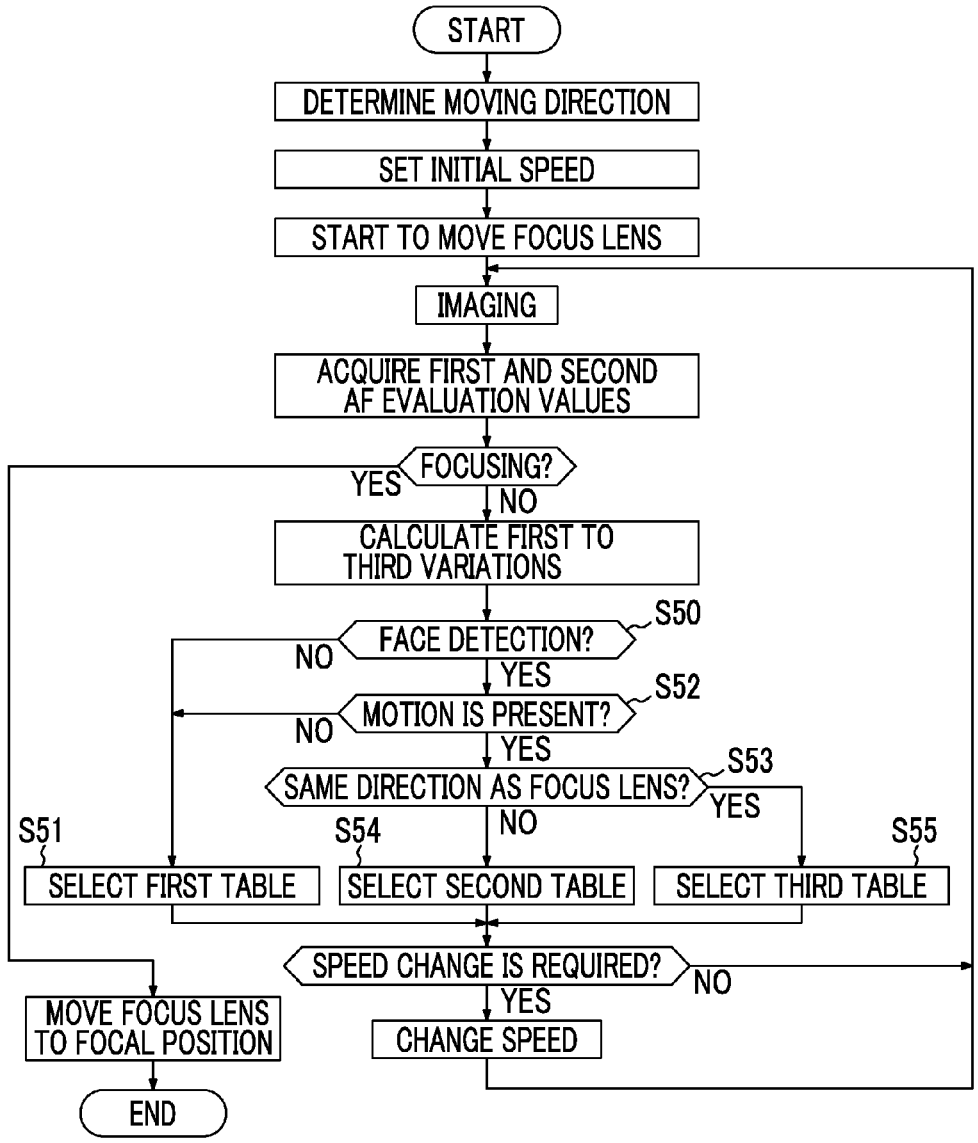

START
DETERMINE MOVING DIRECTION
SET INITIAL SPEED
START TO MOVE FOCUS LENS
IMAGING
ACQUIRE FIRST AND SECOND AF EVALUATION VALUES
FOCUSING?
YES
NO
CALCULATE FIRST TO THIRD VARIATIONS
S50
FACE DETECTION?
NO
YES
S52
MOTION IS PRESENT?
NO
YES
S53
SAME DIRECTION AS FOCUS LENS?
YES
NO
S51
S54
S55
SELECT FIRST TABLE
SELECT SECOND TABLE
SELECT THIRD TABLE
SPEED CHANGE IS REQUIRED?
NO
YES
CHANGE SPEED
MOVE FOCUS LENS TO FOCAL POSITION
END

FIG. 21

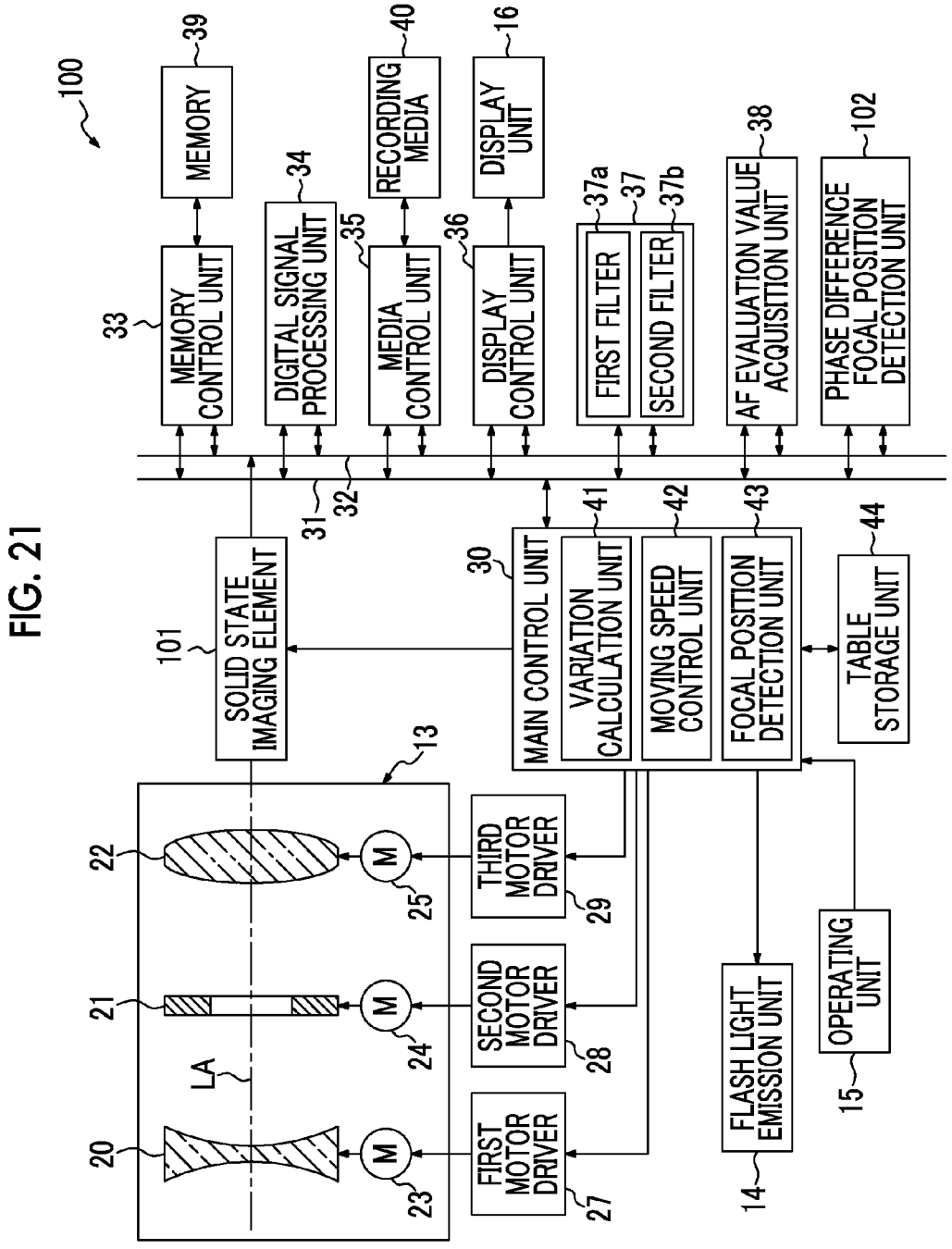

100
MEMORY
39
RECORDING MEDIA
40
DISPLAY UNIT
16
MEMORY CONTROL UNIT
33
DIGITAL SIGNAL PROCESSING UNIT
34
MEDIA CONTROL UNIT
35
DISPLAY CONTROL UNIT
36
FIRST FILTER
37a
SECOND FILTER
37b
37
AF EVALUATION VALUE ACQUISITION UNIT
38
PHASE DIFFERENCE FOCAL POSITION DETECTION UNIT
102
31
32
SOLID STATE IMAGING ELEMENT
101
MAIN CONTROL UNIT
30
VARIATION CALCULATION UNIT
41
MOVING SPEED CONTROL UNIT
42
FOCAL POSITION DETECTION UNIT
43
TABLE STORAGE UNIT
44
13
22
21
20
LA
M
25
24
23
THIRD MOTOR DRIVER
29
SECOND MOTOR DRIVER
28
FIRST MOTOR DRIVER
27
FLASH LIGHT EMISSION UNIT
14
OPERATING UNIT
15

FIG. 22

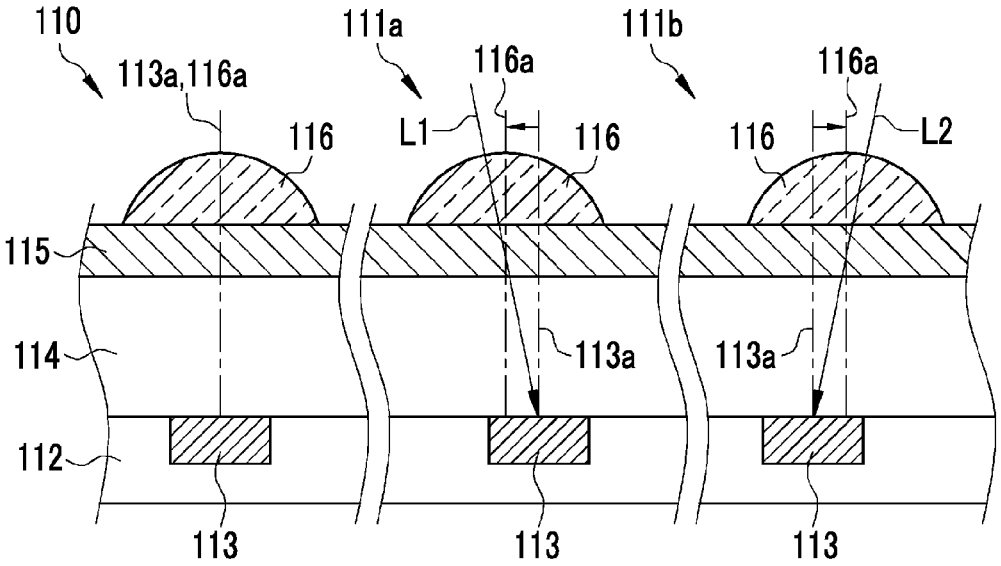

110
113a,116a
116
111a
116a
L1
116
111b
116a
116
L2
115
114
113a
113a
112
113
113
113

FIG. 23

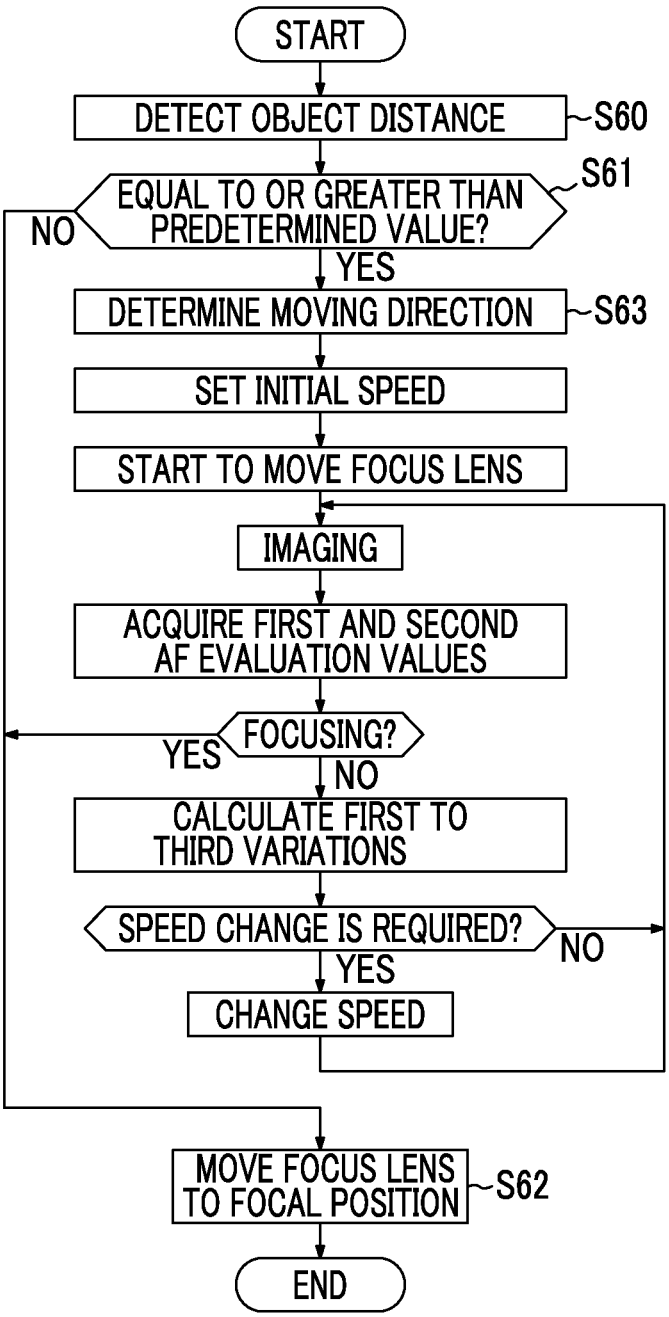

START
DETECT OBJECT DISTANCE
S60
EQUAL TO OR GREATER THAN PREDETERMINED VALUE?
S61
NO
YES
DETERMINE MOVING DIRECTION
S63
SET INITIAL SPEED
START TO MOVE FOCUS LENS
IMAGING
ACQUIRE FIRST AND SECOND AF EVALUATION VALUES
FOCUSING?
YES
NO
CALCULATE FIRST TO THIRD VARIATIONS
SPEED CHANGE IS REQUIRED?
NO
YES
CHANGE SPEED
MOVE FOCUS LENS TO FOCAL POSITION
S62
END

FIG. 24

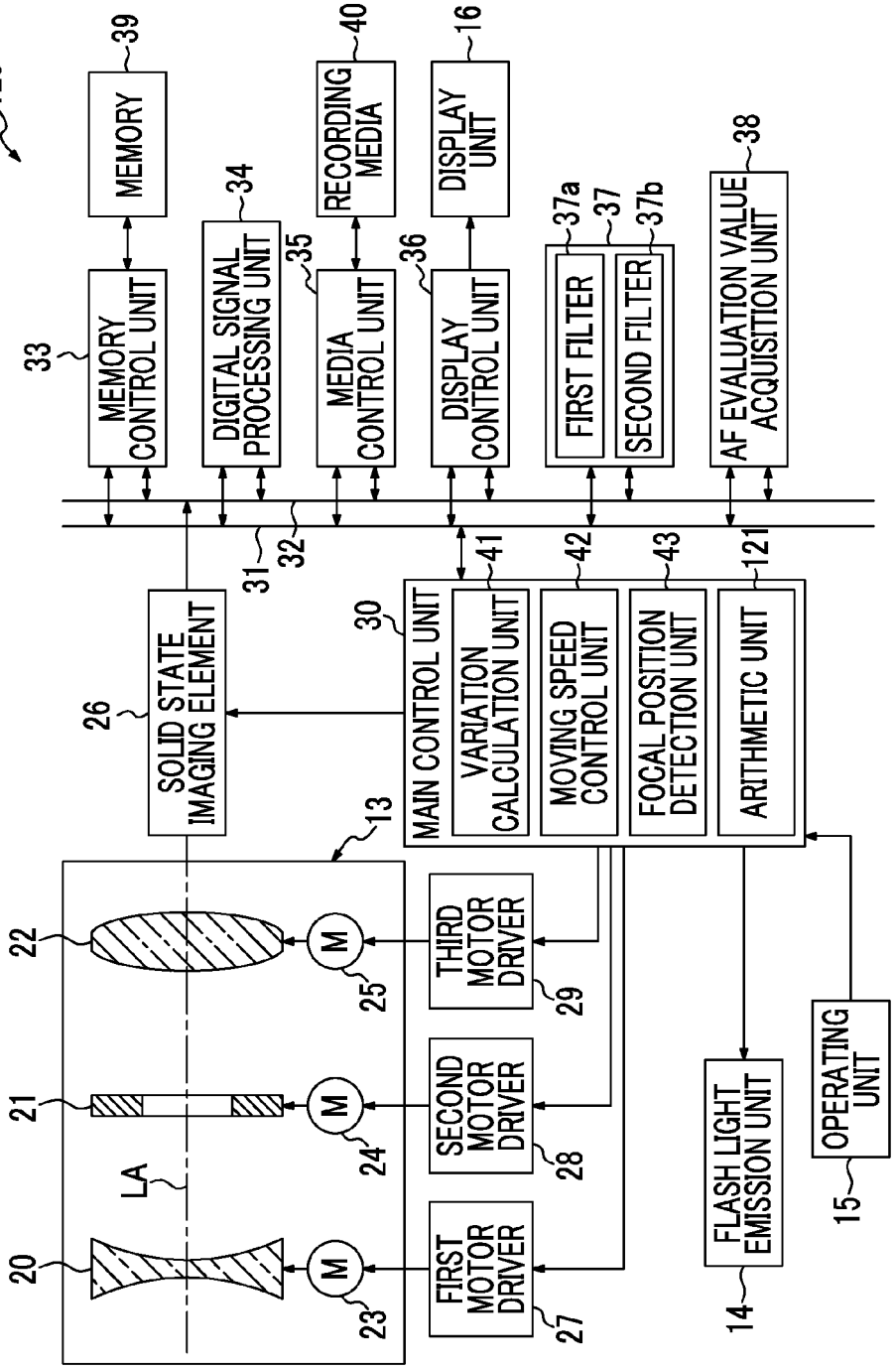
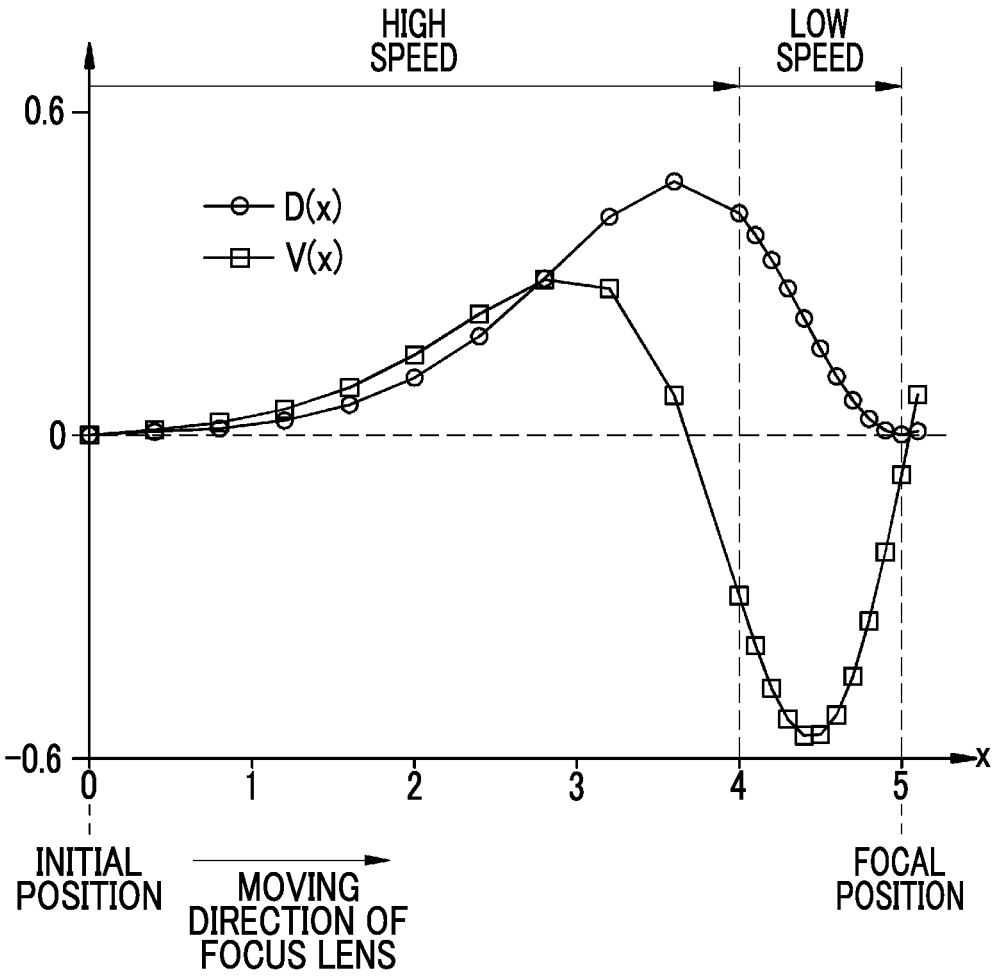

120
MEMORY
39
RECORDING MEDIA
40
DISPLAY UNIT
16
MEMORY CONTROL UNIT
33
DIGITAL SIGNAL PROCESSING UNIT
34
MEDIA CONTROL UNIT
35
DISPLAY CONTROL UNIT
36
FIRST FILTER
37a
SECOND FILTER
37b
37
AF EVALUATION VALUE ACQUISITION UNIT
38
31
32
SOLID STATE IMAGING ELEMENT
26
MAIN CONTROL UNIT
30
VARIATION CALCULATION UNIT
41
MOVING SPEED CONTROL UNIT
42
FOCAL POSITION DETECTION UNIT
43
ARITHMETIC UNIT
121
13
22
21
20
LA
M
25
24
23
THIRD MOTOR DRIVER
29
SECOND MOTOR DRIVER
28
FIRST MOTOR DRIVER
27
FLASH LIGHT EMISSION UNIT
14
OPERATING UNIT
15

FIG. 25


HIGH SPEED
LOW SPEED
0.6
0
-0.6
D(x)
V(x)
0
1
2
3
4
5
x
INITIAL POSITION
MOVING DIRECTION OF FOCUS LENS
FOCAL POSITION

PHOTOGRAPHIC APPARATUS AND METHOD FOR FOCUSING CONTROL USING TWO HIGH PASS FILTERS

CROSS-REFERENCE TO RELATED APPLICATIONS

This application is a Continuation of PCT International Application No. PCT/JP2014/069175 filed on Jul. 18, 2014, which claims priority under 35 U.S.C §119(a) to Japanese Patent Application No. 2013-160395 filed Aug. 1, 2013. The above application is hereby expressly incorporated by reference, in its entirety, into the present application.

BACKGROUND OF THE INVENTION

1. Field of the Invention

The present invention relates to a photographing method and apparatus which photographs an object while performing auto focus of a contrast system.

2. Description Related to the Prior Art

A photographing apparatus, such as a digital camera, includes a focus lens, a lens drive unit which moves the focus lens in an optical axis direction, and an imaging unit which images the object through the focus lens to generate image data. Such a photographing apparatus is normally provided with an auto focus (AF) function of automatically executing a focusing operation without any user operation. As the AF function, a contrast system in which a focal position where image contrast is the highest is detected while moving a focus lens is generally used.

The AF function of the contrast system is realized by a frequency component extraction unit, an AF evaluation value acquisition unit, and a focal position detection unit. The frequency component extraction unit extracts a predetermined spatial frequency component from each piece of image data, which is generated through imaging with an imaging unit at an interval of a predetermined time while moving the focus lens, using a high pass filter. The AF evaluation value acquisition unit integrates the extracted spatial frequency component to acquire an AF evaluation value representing contrast. The focal position detection unit detects the focal position of the focus lens searches by searching for a peak position of the AF evaluation value.

Since the peak of the AF evaluation value does not appear if the focus lens does not actually pass the focal position, when the moving speed of the focus lens is high, the moving pitch of the focus lens is great, and the focus lens may greatly depart from the focal position. In this case, as described in United States Patent Application Publication No. 2011/0261251 (corresponding to WO2010/050200A), after the focus lens passes through the focal position, the moving speed of the focus lens is changed to a low speed to reduce the moving pitch, whereby it is possible to detect the focal position with excellent accuracy. However, it takes a long time until the focus lens is returned to the focal position after greatly departing from the focal position.

In response to this problem, JP2012-103708A suggests that first and second AF evaluation values are acquired using a first high pass filter having a first cutoff frequency and a second high pass filter having a second cutoff frequency higher than the first cutoff frequency, and moving control of a focus lens is performed with the quotient obtained by dividing the first AF evaluation value by the second AF evaluation value as a parameter.

In this parameter, a peak appears at a position separated by a predetermined amount from the focal position. "Coarse adjustment" of the focus lens is performed from when the focus lens starts to move until the peak of the parameter is detected, and "fine adjustment" is performed after the peak is detected. Specifically, moving of the focus lens is temporarily stopped when the peak of the parameter is detected, and thereafter, moving of the focus lens is performed based on the second AF evaluation value. The first and second cutoff frequencies are set such that the peak position of the parameter becomes about twice the moving pitch of the focus lens from the focal position, whereby the time necessary for fine adjustment is reduced and the AF operation time is reduced.

However, in the photographing apparatus described in JP2012-103708A, while coarse adjustment is performed if moving of the focus lens is started and is changed to fine adjustment when the focus lens reaches a position separated by a predetermined amount from the focal position, at this time, control for the moving speed of the focus lens is not performed. For this reason, when the moving pitch of the focus lens is great, since the focus lens greatly departs from the focal position, the AF operation time is extended.

Furthermore, since the distance between the peak position of the parameter and the focal position depends on the first and second cutoff frequencies, in order to reduce the AF operation time, it is necessary to appropriately set the first and second cutoff frequencies. When this setting is not appropriate, the AF operation time is not reduced.

SUMMARY OF THE INVENTION

An object of the invention is to provide a photographing method and apparatus capable of easily reducing an AF operation time.

An object of the invention is to provide a photographing method and apparatus capable of easily reducing an AF operation time.

In order to attain the above-described object, an imaging apparatus of an aspect of the invention includes a focus lens, a lens drive unit, an imaging unit, a frequency component extraction unit, an AF evaluation value acquisition unit, an arithmetic unit, a variation calculation unit, a moving speed control unit, and a focal position detection unit. The lens drive unit moves the focus lens in an optical axis direction. The imaging unit images an object at an interval of a predetermined time through the focus lens moving in the optical axis direction, and generates a plurality of pieces of image data. The frequency component extraction unit extracts a spatial frequency component from each piece of image data using a first filter and a second filter as high pass filters. A cutoff frequency of the first filter is higher than a cutoff frequency of the second filter. The AF evaluation value acquisition unit integrates the spatial frequency component extracted by the first filter to acquire a first AF evaluation value, and integrates the spatial frequency component extracted by the second filter to acquire a second AF evaluation value. The arithmetic unit subtracts a value obtained by multiplying or adding a predetermined constant to the first AF evaluation value from the second AF evaluation value to calculate an arithmetic value. The variation calculation unit calculates a variation of the arithmetic value at an interval of the predetermined time. The moving speed control unit controls a moving speed of the focus lens by the lens drive unit based on the variation. The focal position detection unit detects a focal position of the focus lens based on at least one of the first AF evaluation value and the second AF evaluation value.

An imaging apparatus of another aspect of the invention includes a focus lens, a lens drive unit, an imaging unit, a frequency component extraction unit, an AF evaluation value acquisition unit, a variation calculation unit, a moving speed control unit, a focal position detection unit, a difference calculation unit, and a table storage unit. The lens drive unit moves the focus lens in an optical axis direction. The imaging unit images an object at an interval of a predetermined time through the focus lens moving in the optical axis direction, and generates a plurality of pieces of image data. The frequency component extraction unit extracts a spatial frequency component from each piece of image data using a first filter and a second filter as high pass filters. A cutoff frequency of the first filter is higher than a cutoff frequency of the second filter. The AF evaluation value acquisition unit integrates the spatial frequency component extracted by the first filter to acquire a first AF evaluation value, and integrates the spatial frequency component extracted by the second filter to acquire a second AF evaluation value. The variation calculation unit calculates at least a first variation corresponding to first-order differentiation of the first AF evaluation value and a second variation corresponding to first-order differentiation of the second AF evaluation value at an interval of the predetermined time. The moving speed control unit controls a moving speed of the focus lens by the lens drive unit based on the first variation and the second variation. The focal position detection unit detects a focal position of the focus lens based on at least one of the first AF evaluation value and the second AF evaluation value. The difference calculation unit calculates a difference between the first AF evaluation value and the second AF evaluation value. The table storage unit stores a plurality of tables defining at least a correspondence relationship between rates of increase or decrease of the first and second variations and the moving speed. The correspondence relationship is different according to the difference. The moving speed control unit selects a table corresponding to the difference calculated by the difference calculation unit from among the plurality of tables, and controls the moving speed of the focus lens by the lens drive unit based on the selected table.

The variation calculation unit preferably calculates a third variation corresponding to second-order differentiation of the second AF evaluation value at an interval of the predetermined time in addition to the first and second variations. The table storage unit preferably stores a plurality of tables in which the rates of increase or decrease of the first to third variations are associated with the moving speed.

An imaging apparatus of a further aspect of the invention includes a focus lens, a lens drive unit, an imaging unit, a frequency component extraction unit, an AF evaluation value acquisition unit, a variation calculation unit, a moving speed control unit, a focal position detection unit, a luminance detection unit, and a table storage unit. The lens drive unit moves the focus lens in an optical axis direction. The imaging unit images an object at an interval of a predetermined time through the focus lens moving in the optical axis direction, and generates a plurality of pieces of image data. The frequency component extraction unit extracts a spatial frequency component for each filter constituting a plurality of high pass filters using the plurality of high pass filters having different cutoff frequencies from each piece of image data. The AF evaluation value acquisition unit integrates the spatial frequency component extracted for each filter to acquire an AF evaluation value group composed of a plurality of AF evaluation values. The variation calculation unit calculates a variation of a value based on the AF evaluation value group at an interval of the predetermined time. The moving speed control unit controls a moving speed of the focus lens by the lens drive unit based on the variation. The focal position detection unit detects a focal position of the focus lens based on at least one AF evaluation value of the AF evaluation value group. The luminance detection unit detects a luminance of the object. The table storage unit stores a plurality of tables defining a correspondence relationship between rates of increase or decrease of the variations and the moving speed. The correspondence relationship is different according to the luminance. The moving speed control unit selects a table corresponding to the luminance detected by the luminance detection unit from among the plurality of tables, and controls the moving speed of the focus lens by the lens drive unit based on the selected table.

Preferably, the photographing apparatus further includes at least one pair of phase difference pixels provided in the imaging unit, and a phase difference focal position detection unit which detects the focal position with the phase difference pixels. The moving speed control unit preferably sets an initial speed for starting to move the focus lens to a predetermined value by the lens drive unit in the case where the distance between the position of the focus lens and the focal position detected by the phase difference focal position detection unit is equal to or greater than a predetermined value.

Preferably, each of the first filter and the second filter is a digital filter which subjects each piece of image data to a discrete cosine transformation process to extract the spatial frequency component.

According to the invention, since the variation of the value based on the AF evaluation value is calculated at an interval of the predetermined time, and the moving speed of the focus lens is controlled based on the calculated variation, it is possible to easily reduce an AF operation time.

BRIEF DESCRIPTION OF DRAWINGS

For more complete understanding of the present invention, and the advantage thereof, reference is now made to the subsequent descriptions taken in conjunction with the accompanying drawings, in which:

FIG. **1** is a front-side perspective view of a digital camera;

FIG. **2** is a rear view of the digital camera;

FIG. **3** is a block diagram showing the electrical configuration of the digital camera;

FIG. **4** is a graph showing a characteristic curve of first and second filters;

FIG. **5** is a diagram showing a table which is stored in a table storage unit;

FIG. **6** is a flowchart illustrating an AF operation;

FIG. **7** is a graph showing a simulation result of the AF operation;

FIG. **8** is a block diagram showing the electrical configuration of a digital camera of a second embodiment;

FIG. **9** is a diagram showing a table which is used in the second embodiment;

FIG. **10** is a block diagram showing the electrical configuration of a digital camera of a third embodiment;

FIG. **11** is a diagram showing a table which is used in the third embodiment;

FIG. **12** is a flowchart illustrating an AF operation of the third embodiment;

FIG. **13** is a flowchart illustrating an AF operation of a fourth embodiment;

FIG. **14** is a block diagram showing the electrical configuration of a digital camera of a fifth embodiment;

FIG. **15** is a diagram showing a table which is used in the fifth embodiment;

FIG. **16** is a flowchart illustrating an AF operation of the fifth embodiment;

FIG. **17** is a block diagram showing the electrical configuration of a digital camera of a sixth embodiment;

FIG. **18** is a block diagram showing the electrical configuration of a digital camera of a seventh embodiment;

FIG. **19** is a diagram showing a table which is used in the seventh embodiment;

FIG. **20** is a flowchart illustrating an AF operation of the seventh embodiment;

FIG. **21** is a block diagram showing the electrical configuration of a digital camera of an eighth embodiment;

FIG. **22** is a sectional view showing the configuration of a solid state imaging element of the eighth embodiment;

FIG. **23** is a flowchart illustrating an AF operation of the eighth embodiment;

FIG. **24** is a block diagram showing the electrical configuration of a digital camera of a ninth embodiment; and

FIG. **25** is a graph showing a simulation result of an AF operation of the ninth embodiment.

DESCRIPTION OF THE PREFERRED EMBODIMENTS

First Embodiment

In FIGS. **1** and **2**, a digital camera **11** includes a camera body **12**, a lens barrel **13**, a flash emission unit **14**, an operating unit **15**, and a display unit **16**. The lens barrel **13** is provided on the front surface of the camera body **12**. The flash emission unit **14** is provided on the front surface of the camera body **12**, and emits a flash toward an object for photographing.

The operating unit **15** has a power button **17**, a release button **18**, a mode selection button **19**, and the like, and is provided in the upper portion of the camera body **12**. The power button **17** is operated for turning on/off a power supply (not shown) of the digital camera **11**. The release button **18** is operated for executing photographing. The mode selection button **19** is operated for switching an operation mode of the digital camera **11**. Various photographing scenes (indoor, figure, night view) can be set by the mode selection button **19** and the like.

The release button **18** has a two-stage stroke type switch (not shown) constituted of an S**1** switch and an S**2** switch. If the release button **18** is depressed (half-depressed) and the S**1** switch is turned to an on state, the digital camera **11** performs a photographing preparation operation, such as an auto focus (AF) operation. If the release button **18** is further depressed (full-depressed) in this state, and the S**2** switch is turned to an on state, a photographing operation is performed.

The operation mode of the digital camera **11** includes a still image photographing mode in which a still image is acquired, a moving image photographing mode in which a moving image is acquired, a reproduction mode in which each acquired image is reproduced and displayed on the display unit **16**, and the like. The display unit **16** is constituted of a liquid crystal display or the like, and displays images acquired in various photographing modes, or a menu screen for performing various settings.

When the operation mode is set to the still image photographing mode or the moving image photographing mode, the display unit **16** displays a live view image until photographing is executed. The user can determine composition while observing the live view image displayed on the display unit **16**.

The digital camera **11** is provided with a slot (not shown) into which a recording media **40** (see FIG. **3**) described below is loaded.

In FIG. **3**, the lens barrel **13** is provided with a variable magnification lens **20**, a diaphragm **21**, and a focus lens **22** arranged along an optical axis LA, and first to third motors **23** to **25** which drive the variable magnification lens **20**, the diaphragm **21**, and the focus lens **22**. On the light emission side of the lens barrel **13**, a solid state imaging element **26** as an imaging unit is provided. The variable magnification lens **20** is constituted of one lens or a plurality of lenses, is driven by the first motor **23** to move in the optical axis direction, and changes the size (magnification) of an object image formed on a light reception surface of the solid state imaging element **26**.

The diaphragm **21** is constituted of a plurality of movable blades which form an aperture **21***a*. In the diaphragm **21**, a plurality of blades are driven by the second motor **24** to change the size of the aperture **21***a*, whereby the amount of light passing through the aperture **21***a* is changed. The focus lens **22** is constituted of one lens or a plurality of lenses, is driven by the third motor **25** to move in the optical axis direction, and changes the focusing state of the object image formed on the light reception surface of the solid state imaging element **26**.

The first to third motors **23** to **25** are a stepping motor or a servo motor, and are respectively driven by first to third motor drivers **27** to **29**. The first to third motor drivers **27** to **29** respectively control the first to third motors **23** to **25** under the control of a main control unit **30**. In this embodiment, the third motor **25** and the third motor driver **29** constitute a lens drive unit which moves the focus lens **22** in the optical axis direction.

The flash emission unit **14** performs a flash emission operation under the control of the main control unit **30**. The main control unit **30** integrally controls the entire digital camera **11** based on an operation signal input from the operating unit **15**.

The solid state imaging element **26** is, for example, a single-plate color imaging type CMOS image sensor having a color filter of an RGB system, and has a light reception surface constituted of a plurality of pixels (not shown) arranged in a two-dimensional matrix. Each pixel includes a photoelectric conversion element, and photoelectrically converts the object image formed on the light reception surface by the lens barrel **13** to an imaging signal.

The solid state imaging element **26** includes signal processing circuits (all are not shown), such as a noise elimination circuit, an auto gain controller, and an A/D conversion circuit. The noise elimination circuit subjects the imaging signal to a noise elimination process. The auto gain controller amplifies the level of the imaging signal to an optimum value. The A/D conversion circuit converts the imaging signal to a digital signal and outputs the digital signal from the solid state imaging element **26**. An output signal of the solid state imaging element **26** is image data (so-called RAW data) having one color signal for each pixel.

The solid state imaging element **26** is driven and controlled by the main control unit **30** according to the photographing mode selected by the mode selection button **19**.

The main control unit **30** controls the respective units based on the photographing mode selected by the mode selection button **19** or predetermined photographing conditions according to a photographing scene.

The main control unit **30** is connected to a control bus **31**. The solid state imaging element **26** is connected to a data bus **32**. A memory control unit **33**, a digital signal processing unit **34**, a media control unit **35**, a display control unit **36**, a frequency component extraction unit **37**, and an AF evaluation value acquisition unit **38** are connected to the control bus **31** and the data bus **32**.

A temporary storage memory **39**, such as an SDRAM, is connected to the memory control unit **33**. The memory control unit **33** inputs image data output from the solid state imaging element **26** to the memory **39** and stores image data in the memory **39**. The memory control unit **33** outputs image data stored in the memory **39** to the digital signal processing unit **34**.

The digital signal processing unit **34** subjects image data (RAW data) input from the memory **39** to a defect correction process, a demosaic process, a gamma correction process, a white balance correction process, a YC conversion process, and the like, and generates YC image data having a luminance signal Y and a color difference signal C.

The media control unit **35** controls recording and reading of an image file in and from the recording media **40**. The recording media **40** is, for example, a memory card embedded with a flash memory or the like. The format of an image file recorded in the recording media **40** is set by the operating unit **15**.

In the case of the still image photographing mode, as an image file, for example, compressed image data where YC image data is compressed based on the JPEG standard or the like is recorded in the recording media **40**. In the case of the moving image photographing mode, moving image data where YC image data of a plurality of frames obtained by moving image photographing is compressed based on the MPEG-4 standard or the like is recorded in the recording media **40**. The compression processes are performed by the digital signal processing unit **34**. In the case of the moving image photographing mode, while sound is acquired and recorded in addition to an image, in this embodiment, description of a configuration relating to sound acquisition and recording will be omitted.

The display control unit **36** controls image display on the display unit **16**. The display control unit **36** converts YC image data generated by the digital signal processing unit **34** to a video signal based on the NTSC standard or the like and outputs the video signal to the display unit **16**.

The frequency component extraction unit **37** has a first filter **37***a* and a second filter **37***b*. The first and second filters **37***a* and **37***b* are digital filters which subject the luminance signal of YC image data to discrete cosine transformation and extract a predetermined spatial frequency component. Specifically, as shown in FIG. **4**, a characteristic curve K**1** of the first filter **37***a* has a first cutoff frequency f**1**. A characteristic curve K**2** of the second filter **37***b* has a second cutoff frequency f**2** higher than the first cutoff frequency f**1**. The first filter **37***a* passes a first spatial frequency component higher than the first cutoff frequency f**1**. The second filter **37***b* passes a second spatial frequency component higher than the second cutoff frequency f**2**.

The luminance signal which is used when the frequency component extraction unit **37** extracts the first and second spatial frequency components is a luminance signal within an AF area (not shown) set in the light reception surface of the solid state imaging element **26**. The AF area can be set by the operating unit **15**. An AF area suitable for a photographing scene can be automatically set by the main control unit **30**.

The AF evaluation value acquisition unit **38** is constituted of an integrator. The AF evaluation value acquisition unit **38** integrates the first spatial frequency component extracted by the first filter **37***a* to generate a first AF evaluation value, and integrates the second spatial frequency component extracted by the second filter **37***b* to generate a second AF evaluation value.

The main control unit **30** has a CPU and an internal memory which stores a processing program, and controls the respective units according to the flow defined in the processing process. At the time of the AF operation, the main control unit **30** performs control such that the third motor driver **29** moves the focus lens **22** along the optical axis LA, and drives the solid state imaging element **26**, the memory control unit **33**, the frequency component extraction unit **37**, and the AF evaluation value acquisition unit **38** in a predetermined period PT. With this, at the time of the AF operation, the first and second AF evaluation values are acquired at an interval of the predetermined time PT.

In the main control unit **30**, a variation calculation unit **41**, a moving speed control unit **42**, and a focal position detection unit **43** are constituted. The variation calculation unit **41** calculates variations of the first and second AF evaluation values at an interval of the predetermined time PT. Specifically, the variation calculation unit **41** calculates a first variation corresponding to first-order differentiation of the first AF evaluation value, a second variation corresponding to first-order differentiation of the second AF evaluation value, and a third variation corresponding to second-order differentiation of the second AF evaluation value.

If the lens position of the focus lens **22** is "x", the moving distance for the predetermined time PT when the focus lens **22** moves at a "low speed" described below is "Δx", and the first and second AF evaluation values at the lens position "x" are respectively $E_1(x)$ and $E_2(x)$ the first to third variations $V_1(x)$ to $V_3(x)$ are represented by Expressions (1) to (3).

$$V_1(x)=\{E_1(x)-E_1(x-\Delta x)\}/\Delta x \quad (1)$$

$$V_2(x)=\{E_2(x)-E_2(x-\Delta x)\}/\Delta x \quad (2)$$

$$V_3(x)=\{V_2(x)-V_2(x-\Delta x)\}/\Delta x \quad (3)$$

Here, $E_1(x-\Delta x)$ and $E_2(x-\Delta x)$ are the first and second AF evaluation values at the lens position "x−Δx" before the predetermined time PT from the lens position "x".

When the focus lens **22** moves at a "high speed" or a "medium speed" described below, since the moving distance of the focus lens **22** for the predetermined time PT is greater than the distance Δx, the variation calculation unit **41** determines $E_1(x-\Delta x)$ and $E_2(x-\Delta x)$ by an interpolation arithmetic operation.

A table storage unit **44** which stores a table TB shown in FIG. **5** is connected to the main control unit **30**. The table storage unit **44** is constituted of a nonvolatile memory, such as a flash memory. In the table TB, the correspondence relationship between the rates $RV_1(x)$ to $RV_3(x)$ of increase or decrease of the first to third variations $V_1(x)$ to $V_3(x)$ and the moving speed SP of the focus lens **22** is defined. The rates $RV_1(x)$ to $RV_3(x)$ of increase or decrease are represented by Expressions (4) to (6).

$$RV_1(x)=\{V_1(x)-V_1(x-\Delta x)\}/V_1(x) \quad (4)$$

$$RV_2(x)=\{V_2(x)-V_2(x-\Delta x)\}/V_2(x) \quad (5)$$

$$RV_3(x)\{V_3(x)-V_3(x-\Delta x)\}/V_3(x) \quad (6)$$

In the table TB, "+" indicates that the rate of increase or decrease is greater than a threshold value T**1** (T**1**>0) and is

increasing. "−" indicates that the rate of increase or decrease is smaller than a threshold value T2 (T2<0) and is decreasing. "0" indicates that the rate of increase or decrease is equal to or greater than the threshold value T2 and equal to or less than the threshold value T1, and is not substantially increased or decreased. In this embodiment, for example, T1=0.01 and T2=−0.01 are set. "H", "M", and "L" respectively represent the "high speed", the "medium speed", and the "low speed". In this embodiment, for example, it is assumed that the medium speed is a speed twice the low speed, and the high speed is a speed is a speed four times the low speed.

The moving speed control unit **42** controls the moving speed of the focus lens **22** based on the rates of increase or decrease of the first to third variations $V_1(x)$ to $V_3(x)$ calculated by the variation calculation unit **41** referring to the table TB. Specifically, the moving speed control unit **42** acquires the first to third variations $V_1(x)$ to $V_3(x)$ from the variation calculation unit **41** at an interval of the predetermined time PT, and calculates the rates $RV_1(x)$ to $RV_3(x)$ of increase or decrease to extract a corresponding speed SP from the table TB. The moving speed control unit **42** changes the speed of the focus lens **22** to the extracted SP when the speed SP extracted from the table TB is different from the current speed of the focus lens **22**.

The focal position detection unit **43** specifies the focal position of the focus lens **22** by detecting the peak of at least one of the first and second AF evaluation values $E_1(x)$ and $E_2(x)$. Specifically, the focal position detection unit **43** monitors change in the first and second AF evaluation values $E_1(x)$ and $E_2(x)$ acquired by the AF evaluation value acquisition unit **38** at an interval of the predetermined time PT, basically detects a position P**1** of the focus lens **22** where the first AF evaluation value $E_1(x)$ becomes a maximum value, and specifies the position P**1** as the focal position. When the maximum value of the first AF evaluation value $E_1(x)$ is smaller than a predetermined value, or when a peak is not detected at the first AF evaluation value $E_1(x)$, the focal position detection unit **43** detects a position P**2** of the focus lens **22** where the second AF evaluation value $E_2(x)$ becomes a maximum value, and specifies the position P**2** as the focal position.

For starting the AF operation, the main control unit **30** determines whether or not the moving direction of the focus lens **22** is toward a FAR side and a NEAR side, and moves the focus lens **22** in the determined direction.

Specifically, at the time of the start of the AF operation, the main control unit **30** moves the focus lens **22** by a distance Δx from the current position toward the FAR side and the NEAR side while allowing the solid state imaging element **26** to perform imaging, and moves the focus lens **22** in a direction in which the first and second AF evaluation values $E_1(x)$ and $E_2(x)$ increase. When the increase directions of the first and second AF evaluation values $E_1(x)$ and $E_2(x)$ are different, for example, the focus lens **22** is moved in the increase direction of the first AF evaluation value $E_1(x)$. At the time of the AF operation, the moving speed control unit **42** sets the moving speed of the focus lens **22** to the "low speed".

The main control unit **30** performs auto exposure (AE) control for detecting the exposure of the solid state imaging element **26** based on the luminance signal of YC image data and controlling the second motor driver **28** based on the detected exposure to adjust the size of the aperture **21***a* of the diaphragm **21** to a proper exposure. The detailed description of the AE control will be omitted.

Next, the action of the digital camera **11** will be described. First, if the power button **17** is operated by the user and the power supply is turned to an on state, a power supply voltage is supplied to the respective units of the digital camera **11**. If the mode selection button **19** is operated by the user and the operation mode is set to the still image photographing mode or the moving image photographing mode, the display (hereinafter, referred to as live view display) of the live view image is displayed on the display unit **16**.

The live view display is performed when the main control unit **30** causes the solid state imaging element **26** to repeatedly perform an imaging operation in a period PT and displays an image based on image data output from the solid state imaging element **26** on the display unit **16** through the display control unit **36**. During the live view display, the AF operation and the AE control are repeatedly performed. The user can determine composition while viewing the live view display and can perform imaging.

When the operation mode is the still image photographing mode, if the release button **18** is half-depressed by the user, the AF operation and the AE control are performed. Thereafter, if the release button **18** is full-depressed, image data obtained by the solid state imaging element **26** is converted to compressed image data by the digital signal processing unit **34**, and is recorded in the recording media **40** through the media control unit **35**.

When the operation mode is the moving image photographing mode, image data of multiple frames obtained by the solid state imaging element **26** in a period during which the release button is full-depressed again after the release button **18** is full-depressed is converted to moving image data by the digital signal processing unit **34**, and is recorded in the recording media **40** through the media control unit **35**.

Next, the AF operation will be described referring to the flowchart shown in FIG. **6**. If the AF operation starts, the focus lens **22** is moved toward the FAR side and the NEAR side by the distance Δx from the current position by the main control unit **30**, and the direction in which the first and second AF evaluation values $E_1(x)$ and $E_2(x)$ increase is determined as the moving direction (Step S**10**). When the focus lens **22** is positioned at the FAR end and the NEAR end, the acquisition of the first and second AF evaluation values $E_1(x)$ and $E_2(x)$ is not performed, and the direction toward the NEAR side and the FAR side is determined as the moving direction.

After the moving direction of the focus lens **22** is determined, the initial speed of the focus lens **22** is set to the "low speed" by the moving speed control unit **42** (Step S**11**), and the moving of the focus lens **22** starts in the direction determined in Step S**10** (Step S**12**). After the moving of the focus lens **22** starts, the imaging operation is repeatedly performed in the period PT by the solid state imaging element **26** (Step S**13**).

The first and second spatial frequency components are extracted by the frequency component extraction unit **37** each time the imaging operation is performed by the solid state imaging element **26**, and the first and second AF evaluation values $E_1(x)$ and $E_2(x)$ are acquired by the AF evaluation value acquisition unit **38** (Step S**14**). If the first and second AF evaluation values $E_1(x)$ and $E_2(x)$ are acquired, the peak detection of the first and second AF evaluation values $E_1(x)$ and $E_2(x)$ is performed by the focal position detection unit **43** (Step S**15**). For the peak detection, the imaging operation should be performed at least three times.

When no peak is detected in the first and second AF evaluation values $E_1(x)$ and $E_2(x)$, the first to third variations

$V_1(x)$ to $V_3(x)$ are calculated by the variation calculation unit **41** based on the first AF evaluation values $E_1(x)$ and $E_1(x-\Delta x)$ obtained by the last two imaging operations and the second AF evaluation values $E_2(x)$, $E_2(x-\Delta x)$, and $E_2(x-2\Delta x)$ obtained by the last three imaging operations (Step S**16**).

If the first to third variations $V_1(x)$ to $V_3(x)$ are calculated, the rates $RV_1(x)$ to $RV_3(x)$ of increase or decrease are calculated by the moving speed control unit **42**, the corresponding speed SP is extracted from the table TB, and it is determined whether or not a speed change of the focus lens **22** is required (Step S**17**). When the speed SP extracted from the table TB is different from the current speed of the focus lens **22** (in Step S**17**, YES), the speed is changed to the speed SP (Step S**18**). When the extracted speed SP is equal to the current speed of the focus lens **22** (in Step S**17**, NO), a speed change is not performed.

The operations of Steps S**13** to S**17** are repeatedly performed, and in Step S**15**, when a peak is detected in the first AF evaluation value $E_1(x)$, the peak position is specified as the focal position (in Step S**15**, YES), the focus lens **22** is moved to the focal position (Step S**15**), and the AF operation ends. When the maximum value of the first AF evaluation value $E_1(x)$ is smaller than a predetermined value, or when no peak is detected and a peak is detected in the second AF evaluation value $E_2(x)$, the peak position is specified as the focal position, and the focus lens **22** is moved to the focal position.

FIG. **7** shows a simulation result of the AF operation of this embodiment. Both of the first and second AF evaluation values $E_1(x)$ and $E_2(x)$ are defined as a Gaussian function having a peak in an area of $x>0$, and the half-value width of the second AF evaluation value $E_2(x)$ is twice the half-value width of the first AF evaluation value $E_1(x)$.

In order to move the focus lens **22** from an initial position ($x=0$) in the positive direction of x, if the first to third variations $V_1(x)$ to $V_3(x)$ are calculated while increasing x from $x=0$, all of the first to third variations $V_1(x)$ to $V_3(x)$ have an increase tendency ($RV_1(x)>T1$, $RV_2(x)>T1$, $RV_3(x)>T1$). According to the table TB, since this corresponds to the "high speed", thereafter, in order to move the focus lens **22** at a high speed, x is increased by 0.4, and the first to third variations $V_1(x)$ to $V_3(x)$ are calculated each time x is increased.

This tendency is continued, and when $x=2.8$ is reached, the first and second variations $V_1(x)$ and $V_2(x)$ have an increase tendency ($RV_1(x)>T1$, $RV_2(x)>T1$), while the third variation $V_3(x)$ is changed to a decrease tendency ($RV_3(x)<T2$) According to the table TB, since this corresponds to the "medium speed", thereafter, in order to move the focus lens **22** at a medium speed, x is increased by 0.2, and the first to third variations $V_1(x)$ to $V_3(x)$ are calculated each time x is increased.

This tendency is continued, and when $x=3.8$ is reached, the first variation $V_1(x)$ has an increase tendency ($RV_1(x)>T1$), while the second variation $V_2(x)$ is changed to a decrease tendency ($RV_2(x)<T2$) and the third variation $V_3(x)$ is changed to an increase tendency ($RV_3(x)>T1$). According to the table TB, since this corresponds to the "low speed", thereafter, in order to move the focus lens **22** at a low speed, x is increased by 0.1, and the first to third variations $V_1(x)$ to $V_3(x)$ are calculated each time x is increased. This tendency is continued, and a peak is detected in the first and second AF evaluation values $E_1(x)$ and $E_2(x)$ when $x=5.0$.

In this way, after the AF operation starts, when the focus lens **22** approaches the focal position, since the moving speed of the focus lens **22** is changed from the high speed to the medium speed and the low speed, the AF operation time is reduced without deteriorating the detection accuracy of the focal position.

Referring to FIG. **7**, it is understood that the change point from the high speed to the medium speed substantially corresponds to the peak position of the second variation $V_2(x)$, and the change point from the medium speed to the low speed substantially corresponds to the peak position of the third variation $V_3(x)$.

Second Embodiment

In the first embodiment, although the table storage unit **44** stores only one table, a plurality of tables may be stored in the table storage unit **44**, and a table for use in the moving speed control unit **42** may be selected according to predetermined conditions.

In FIG. **8**, a digital camera **50** of a second embodiment is provided with the main control unit **30** further including a difference calculation unit **51**, in addition to the variation calculation unit **41**, the moving speed control unit **42**, and the focal position detection unit **43**. The table storage unit **44** stores first and second tables TB**1** and TB**2** shown in FIG. **9**. Since other configurations are the same as those in the first embodiment, the same parts are represented by the same reference numerals, and description thereof will not be repeated.

The difference calculation unit **51** calculates the difference between the first AF evaluation value $E_1(x)$ and the second AF evaluation value $E_2(x)$ each time the first and second AF evaluation values $E_1(x)$ and $E_2(x)$ are acquired by the AF evaluation value acquisition unit **38**. The difference is the absolute value difference Z ($Z=|E_1(x)-E_2(x)|$) between the first and second AF evaluation values $E_1(x)$ and $E_2(x)$. The moving speed control unit **42** selects the first table TB**1** when the absolute value difference Z is equal to or greater than a predetermined value, and selects the second table TB**2** when the absolute value difference Z is smaller than the predetermined value.

The first table TB**1** is the same as the table TB of the first embodiment. The second table TB**2** is different from the first table TB**1** in speed setting of a portion surrounded by a circle. In the second table TB**2**, when all of the first to third variations $V_1(x)$ to $V_3(x)$ have an increase tendency ($RV_1(x)>T1$, $RV_2(x)$ T**1**, $RV_3(x)>T1$), the "low speed" is set, and when first and second variations $V_1(x)$ and $V_2(x)$ have an increase tendency ($RV_1(x)>T1$, $RV_2(x)>T1$) and the third variation $V_3(x)$ is not increased or decreased ($T1>RV_3(x)>T2$), the "medium speed" is set.

When the spatial frequency of the luminance signal in the AF area inclines toward a high frequency side, the difference between the first and second spatial frequency components extracted by the frequency component extraction unit **37** is small, and the difference between the first and second AF evaluation values $E_1(x)$ and $E_2(x)$ is small. In this case, since the half-value width of the second AF evaluation value $E_2(x)$ is narrowed, and the peak position of the second variation $V_2(x)$ is shifted in a direction of the focal position, if the moving speed of the focus lens **22** is set using the same first table TB**1** as in the first embodiment, the focus lens **22** is moved near the focal position while maintaining the "medium speed" or the "high speed", and the detection accuracy of the focal position may be degraded. In contrast, in this embodiment, since the second table TB**2** is used when the absolute value difference Z is smaller than the predetermined value, and the focus lens **22** is driven at the "low speed" over substantially the entire range from the initial

position to the focal position, degradation of the detection accuracy of the focal position is prevented.

Third Embodiment

In FIG. **10**, a digital camera **60** of a third embodiment includes an object luminance detection unit **61**. The table storage unit **44** stores first and second tables TB**1** and TB**2** shown in FIG. **11**. Since other configurations are the same as those in the first embodiment, the same parts are represented by the same reference numerals, and description thereof will not be repeated.

The object luminance detection unit **61** is connected to the control bus **31** and the data bus **32**. The object luminance detection unit **61** integrates the luminance signal in the AF area to determine the average value, thereby detecting object luminance in the AF area. The moving speed control unit **42** selects the first table TB**1** when the object luminance detected by the object luminance detection unit **61** is equal to or greater than a predetermined value, and selects the second table TB**2** when the object luminance is smaller than the predetermined value.

The first table TB**1** is the same as the table TB of the first embodiment. The second table TB**2** is different from the first table TB**1** in speed setting of a portion surrounded by a circle. In the second table TB**2**, "C" indicates that a set speed is not changed and is continued as it is.

In this embodiment, as shown in the flowchart of FIG. **12**, if the AF operation starts, the object luminance is detected by the object luminance detection unit **61** (Step S**20**), and it is determined whether or not the object luminance is smaller than the predetermined value (Step S**21**). When the object luminance is equal to or greater than the predetermined value (in Step S**21**, NO), the first table TB**1** is selected (Step S**22**). When the object luminance is smaller than the predetermined value (in Step S**21**, YES), the second table TB**2** is selected (Step S**23**). The subsequent steps are the same as those in the first embodiment.

When the object luminance is low, since noise occurs in image data, and the acquisition accuracy of the first and second AF evaluation values and the first to third variations is degraded, if the moving speed of the focus lens **22** is set using the same first table TB**1** as in the first embodiment, a speed change may be frequently performed more than necessary. In contrast, in this embodiment, when the object luminance is lower than the predetermined value, since the second table TB**2** having setting of continuation (C) is used, the number of speed changes is reduced.

Fourth Embodiment

In a digital camera of a fourth embodiment, the table storage unit **44** stores the first and second tables TB**1** and TB**2** shown in FIG. **11**, and the first table TB**1** or the second table TB**2** is selected according to the operation mode (the still image photographing mode or the moving image photographing mode). Since other configurations are the same as those in the first embodiment, the same parts are represented by the same reference numerals, and description thereof will not be repeated.

In this embodiment, as shown in the flowchart of FIG. **13**, if the AF operation starts, the main control unit **30** determines whether or not the operation mode currently set by the mode selection button **19** is the moving image photographing mode (Step S**30**). When the still image photographing mode is set instead of the moving image photographing mode (in Step S**30**, NO), the first table TB**1** is selected (Step S**31**). When the moving image photographing mode is set (in Step S**30**, YES), the second table TB**2** is selected (Step S**32**). The subsequent steps are the same as those in the first embodiment.

At the time of photographing a moving image, if the moving speed of the focus lens **22** is set using the same first table TB**1** as in the first embodiment, a speed change may be frequently performed with the movement of the object; however, in this embodiment, at the time of photographing a moving image, since second table TB**2** having setting of continuation (C) is used, the number of speed changes is reduced.

Fifth Embodiment

In FIG. **14**, a digital camera **70** of a fifth embodiment includes a scene recognition unit **71**. The table storage unit **44** stores first and second tables TB**1** and TB**2** shown in FIG. **15**. Since other configurations are the same as those in the first embodiment, the same parts are represented by the same reference numerals, and description thereof will not be repeated.

The scene recognition unit **71** recognizes the photographing scene (landscape, figure, macro, or the like) of the object imaged by the solid state imaging element **26** based on image data. The scene recognition process is disclosed, for example, in JP2010-034718A. The moving speed control unit **42** selects either of the first and second tables TB**1** and TB**2** according to the photographing scene recognized by the scene recognition unit **71**.

The first table TB**1** is the same as the table TB of the first embodiment. The second table TB**2** is different from the first table TB**1** in that speed setting of a portion surrounded by a circle is the "medium speed" or the "low speed". The second table TB**2** is selected when the photographing scene is "landscape".

In this embodiment, as shown in the flowchart of FIG. **16**, if the AF operation starts, the photographing scene is recognized by the scene recognition unit **71** (Step S**40**), and it is determined whether or not the photographing scene is "landscape" (Step S**41**) When the photographing scene is a scene other than "landscape" (in Step S**41**, NO), the first table TB**1** is selected (Step S**42**) When the photographing scene is "landscape" (in Step S**41**, YES) the second table TB**2** is selected (Step S**43**). The subsequent steps are the same as those in the first embodiment.

When the photographing scene is landscape, such as woods, since an object has many high frequency components, if the moving speed of the focus lens **22** is set using the same first table TB**1** as in the first embodiment, the focus lens **22** is moved to the vicinity of the focal position while maintaining the "high speed", and the detection accuracy of the focal position may be degraded. In this embodiment, when the photographing scene is landscape, since the second table TB**2** is used, and the focus lens **22** is driven at the "medium speed" or the "low speed" over substantially the entire range from the initial position to the focal position, degradation of the detection accuracy of the focal position is prevented.

When the photographing scene is set by the mode selection button **19** or the like, a table may be selected based on the set photographing scene. The number of tables is not limited to two, and three or more tables may be stored in the table storage unit **44** corresponding to various photographing scenes.

Sixth Embodiment

In FIG. **17**, a digital camera **80** of a sixth embodiment includes a point light source detection unit **81**. The table

storage unit **44** stores the first and second tables TB**1** and TB**2** shown in FIG. **11**. Since other configurations are the same as those in the first embodiment, the same parts are represented by the same reference numerals, and description thereof will not be repeated.

The point light source detection unit **81** detects whether or not a point light source exists in an AF area based on image data. The point light source detection process is disclosed, for example, in JP2013-25650A. The point light source is an area where local light having a size equal to or greater than a predetermined size exists. The moving speed control unit **42** selects the first table TB**1** when no point light source is detected by the point light source detection unit **81** immediately after the AF operation starts, and selects the second table TB**2** when the point light source is detected.

If the point light source exists in the AF area, since the acquisition accuracy of the first and second AF evaluation values and the first to third variations is degraded, if the moving speed of the focus lens **22** is set using the same first table TB**1** as in the first embodiment, a speed change may be frequently performed more than necessary. In this embodiment, when the object luminance is lower than the predetermined value, since the second table TB**2** having setting of continuation (C) is used, the number of speed changes is reduced.

Seventh Embodiment

In FIG. **18**, a digital camera **90** of a seventh embodiment includes a face detection unit **91** and a motion detection unit **92**. The table storage unit **44** stores first to third tables TB**1** to TB**3** shown in FIG. **19**. Since other configurations are the same as those in the first embodiment, the same parts are represented by the same reference numerals, and description thereof will not be repeated.

The face detection unit **91** detects a face of a person as an object from each piece of image data generated by the solid state imaging element **26** at an interval of a predetermined time PT. When the face is detected, the face detection unit **91** determines the position and size of the face in the image. The face detection process is disclosed, for example, in JP2012-185846A.

The motion detection unit **92** detects the motion of the object (face) by monitoring the position of the face detected by the face detection unit **91** from each piece of image data generated by the solid state imaging element **26** at an interval of the predetermined time PT. When the motion of the object is detected, the motion detection unit **92** determines the variation rate of the size of the object at an interval of the predetermined time PT, and determines whether or not the motion direction of the object is the same as the moving direction of the focus lens **22** based on the variation rate. The moving speed control unit **42** selects either of the first to third tables TB**1** to TB**3** according to the presence or absence of face detection in the face detection unit **91** and the motion direction of the object detected by the motion detection unit **92**.

The first table TB**1** is the same as the table TB of the first embodiment. The second table TB**2** is different from the first table TB**1** in that speed setting of a portion surrounded by a circle is the "medium speed" or the "low speed". The third table TB**3** is different from the first table TB**1** in that speed setting of a portion surrounded by a circle is the "high speed" or the "medium speed".

In this embodiment, as shown in the flowchart of FIG. **20**, after the AF operation starts and the first to third variations are calculated as described above, face detection is detected by the face detection unit **91** (Step S**50**), and when the face is not detected as the object (in Step S**50**, NO), the first table TB**1** is selected (Step S**51**). When the face is detected (in Step S**50**, YES), motion detection of the object (face) is performed by the motion detection unit **92** (Step S**52**). When motion is not detected in the object (in Step S**52**, NO), the first table TB**1** is selected (Step S**51**).

When motion is detected in the object, it is determined whether or not the motion direction is the same as the moving direction of the focus lens **22** (Step S**53**). When the motion direction is opposite to the moving direction of the focus lens **22** (in Step S**53**, NO), the second table TB**2** is selected (Step S**54**). When the motion direction is the same as the moving direction of the focus lens **22** (in Step S**53**, YES), the third table TB**3** is selected (Step S**55**). The subsequent steps are the same as those in the first embodiment.

When the object is moving in the optical axis direction, the focal position changes. When the motion direction of the object is opposite to the moving direction of the focus lens **22**, since the focal position changes to gradually approach the focus lens **22** side, if the moving speed of the focus lens **22** is set using the same first table TB**1** as in the first embodiment, the focus lens **22** moves to the vicinity of the focal position while maintaining the "high speed", and the detection accuracy of the focal position may be degraded. Conversely, when the motion direction of the object is the same as the moving direction of the focus lens **22**, since the focal position changes in a direction away from the focus lens **22**, the time necessary for focusing may be extended. In this embodiment, since a table having different speed setting is appropriately selected according to the presence or absence of motion of the object and the motion direction, the AF operation is performed in a short period of time and with high accuracy.

In this embodiment, although the face is detected as the object, motion of an object other than the face may be detected. The detection of the motion direction is not limited to the method based on the variation rate of the size of the object.

Eighth Embodiment

In FIG. **21**, a digital camera **100** of an eighth embodiment includes a solid state imaging element **101** which has a phase difference pixel, and a phase difference focal position detection unit **102**. The table storage unit **44** stores the table TB shown in FIG. **5**. Since other configurations are the same as those in the first embodiment, the same parts are represented by the same reference numerals, and description thereof will not be repeated.

As shown in FIG. **22**, the solid state imaging element **101** includes a normal pixel **110**, a first phase difference pixel **111***a*, and a second phase difference pixel **111***b*. Each of the pixels **110**, **111***a*, and **111***b* includes a photodiode **113** which is formed on a semiconductor substrate **112**, an intermediate layer **114** which is formed on the photodiode **113** and has an electrode or a wire, a color filter **115** which is formed on the intermediate layer **114**, and a microlens **116** which is formed on the color filter **115**.

The normal pixel **110** is configured such that a center axis **116***a* of the microlens **116** is substantially aligned with a center axis **113***a* of the photodiode **113**, and does not substantially have direction dependence of light reception sensitivity. The first phase difference pixel **111***a* is configured such that the center axis **116***a* of the microlens **116** is deviated from the center axis **113***a* of the photodiode **113** in

a left direction, and has high sensitivity to incident light L1 from a left oblique direction. Meanwhile, the second phase difference pixel **111***b* is configured such that the center axis **116***a* of the microlens **116** is deviated from the center axis **113***a* of the photodiode **113** in a right direction, and has high sensitivity to incident light L2 from a right oblique direction.

The first and second phase difference pixels **111***a* and **111***b* are arranged in a two-dimensional matrix along with the normal pixel **110**, and constitute a light reception surface. The pixel signals of the first and second phase difference pixels **111***a* and **111***b* are subjected to gain correction, and are then used for generating image data described above with the pixel signal of the normal pixel **110**.

The phase difference focal position detection unit **102** detects the focal position by determining the amount of deviation between a first image obtained by the pixel signal of the first phase difference pixel **111***a* and a second image obtained by the pixel signal of the second phase difference pixel **111***b*. The focusing detection process of the phase difference system is disclosed, for example, in JP2012-203314A.

In this embodiment, as shown in the flowchart of FIG. **23**, if the AF operation starts, imaging is performed by the solid state imaging element **101**, and the focal position is detected by the phase difference focal position detection unit **102** (Step S**60**). The main control unit **30** determines whether or not the distance (hereinafter, referred to as a focusing distance) between the current position of the focus lens **22** to the focal position is equal to or greater than a predetermined value (Step S**61**).

When the focusing distance is smaller than the predetermined value (in Step S**61**, NO), the focus lens **22** is moved to the focal position detected by the phase difference focal position detection unit **102** (Step S**62**), and the AF operation ends. When the focusing distance is equal to or greater than the predetermined value, as in the first embodiment, after the moving direction of the focus lens **22** is determined (Step S**63**), and the initial speed of the focus lens **22** is set, the AF operation of the contrast system is performed. In this embodiment, for performing the AF operation of the contrast system, since it is known that the object distance is equal to or greater than a predetermined value, the moving speed control unit **42** sets the initial speed to the "high speed".

In this embodiment, since the focal position is detected by the phase difference detection system, and when the focusing distance is smaller than the focusing distance, the detection accuracy of the focal distance detected by the phase difference detection system is comparatively high, the AF operation of the contrast system is not performed, and the focus lens **22** is moved to the focal position. When the focusing distance is equal to or greater than the predetermined value, since the detection accuracy of the focal position is low, the AF operation of the contrast system is executed. In this way, in this embodiment, it is possible to perform the AF operation in a shorter period of time and with higher accuracy.

Ninth Embodiment

In FIG. **24**, a digital camera **120** of a ninth embodiment is provided with the main control unit **30** further including an arithmetic unit **121**, in addition to the variation calculation unit **41**, the moving speed control unit **42**, and the focal position detection unit **43**. In this embodiment, the table storage unit **44** is not provided. Since other configurations are the same as those in the first embodiment, the same parts are represented by the same reference numerals, and description thereof will not be repeated.

The arithmetic unit **121** performs an arithmetic operation based on Expression (7) each time the first and second AF evaluation values $E_1(x)$ and $E_2(x)$ are acquired by the AF evaluation value acquisition unit **38**, and calculates an arithmetic value D(x).

$$D(x)=E_2(x)-\alpha E_1(x) \tag{7}$$

Here, the constant α (positive real number) is a value determined in advance such that the arithmetic value D(x) does not have a peak at the focal position, and has a peak at a lens position away from the focal position to some extent. Specifically, the constant α is determined such that the values of the first and second AF evaluation values $E_1(x)$ and $E_2(x)$ match each other at the focal position by imaging a chart having a specific frequency component.

In this embodiment, the variation calculation unit **41** calculates a variation V(x) corresponding to first-order differentiation of the arithmetic value D(x) based on Expression (8).

$$V(x)=\{D(x)-D(x-\Delta x)\}/\Delta x \tag{8}$$

The moving speed control unit **42** sets the moving speed of the focus lens **22** to the "high speed" when the variation V(x) is positive (V(x)>0), and sets the moving speed of the focus lens **22** to the "low speed" when the variation V(x) is negative (V(x)<0).

FIG. **25** shows a simulation result of the AF operation of this embodiment. The arithmetic value D(x) is determined using the first and second AF evaluation values $E_1(x)$ and $E_2(x)$ shown in FIG. **7** as α=1.

In order to move the focus lens **22** from the initial position (x=0) in the positive direction of x, if the variation V(x) is calculated while increasing x from x=0, the variation V(x) becomes positive (V(x)>0). Since the variation V(x) corresponds to the "high speed", thereafter, in order to move the focus lens **22** at the high speed, x is increased by 0.4, and the variation V(x) is calculated each time x is increased.

When x=4.0, the variation V(x) is changed to negative (V(x)<0). Since the variation V(x) corresponds to the "low speed", thereafter, in order to move the focus lens **22** at the low speed, x is increased by 0.1, and the variation V(x) is calculated each time x is increased. While the variation V(x) remains negative, a peak is detected in the first and second AF evaluation values $E_1(x)$ and $E_2(x)$ when x=5.0.

In this embodiment, after the AF operation starts and before the focus lens **22** approaches the focal position, since the moving speed is changed from the high speed to the low speed, the AF operation time is reduced without deteriorating the detection accuracy of the focal position.

In this embodiment, as shown in Expression (7), although a value obtained by multiplying the first AF evaluation value $E_1(x)$ by the constant α is subtracted from the second AF evaluation value $E_2(x)$, a value obtained by adding a constant β (positive or negative real number) to the first AF evaluation value $E_1(x)$ may be subtracted from the second AF evaluation value $E_2(x)$. In this case, the constant β is a value determined in advance such that an arithmetic value F(x) does not have a peak at the focal position, and has a peak at a lens position away from the focal position to some extent. The constant β is determined such that the first and second AF evaluation values $E_1(x)$ and $E_2(x)$ match each other at the focal position by imaging a chart having a specific frequency component.

A quotient obtained by dividing the first AF evaluation value $E_1(x)$ by the second AF evaluation value $E_2(x)$ may be set as the arithmetic value D(x).

Other Embodiments

In the first to eighth embodiments, although the first to third variations are calculated, and the moving speed of the focus lens **22** is controlled based on the rates of increase or decrease of the first to third variations, only the first and second variations may be calculated, and the moving speed of the focus lens **22** may be controlled based on the rates of increase or decrease of the first and second variations.

In the respective embodiments described above, although the two filters are provided in the frequency component extraction unit **37**, and the two AF evaluation values are acquired by the AF evaluation value acquisition unit **38**, the number of filters of the frequency component extraction unit **37** may be one, and only one AF evaluation value may be acquired. In this case, the variation calculation unit **41** may calculate at least a variation corresponding to first-order differentiation of the AF evaluation value, and the moving speed control unit **42** may control the moving speed of the focus lens **22** based on the variation. In addition, three or more filters may be provided in the frequency component extraction unit **37**, and three or more AF evaluation values may be acquired.

In the respective embodiments described above, although a digital camera is illustrated as an imaging device, the invention can be applied to various apparatuses with an imaging function (imaging devices), such as a video camera, a mobile phone with a camera, and a smartphone. The respective embodiments described above can be combined with one another as long as there is no contradiction

Although the present invention has been fully described by the way of the preferred embodiment thereof with reference to the accompanying drawings, various changes and modifications will be apparent to those having skill in this field. Therefore, unless otherwise these changes and modifications depart from the scope of the present invention, they should be construed as included therein.

What is claimed is:

1. A photographing apparatus comprising:

a focus lens;

a lens drive unit which moves the focus lens in an optical axis direction;

an imaging unit which images an object at an interval of a predetermined time through the focus lens moving in the optical axis direction, and generates a plurality of pieces of image data;

a frequency component extraction unit which extracts a spatial frequency component from each piece of image data using a first filter and a second filter as high pass filters, a cutoff frequency of the first filter being higher than a cutoff frequency of the second filter;

an AF evaluation value acquisition unit which integrates the spatial frequency component extracted by the first filter to acquire a first AF evaluation value, and integrates the spatial frequency component extracted by the second filter to acquire a second AF evaluation value;

an arithmetic unit which subtracts a value obtained by multiplying or adding a predetermined constant to the first AF evaluation value from the second AF evaluation value to calculate an arithmetic value, the arithmetic value being calculated as $E_2-\alpha E_1$ or $E_2-(E_1+\beta)$ where E_1 and E_2 are the first and second AF evaluation values respectively, α is a constant of positive real number, and β is a constant of positive or negative real number;

a variation calculation unit which calculates a variation of the arithmetic value at an interval of the predetermined time;

a moving speed control unit which controls a moving speed of the focus lens by the lens drive unit based on the variation; and

a focal position detection unit which detects a focal position of the focus lens based on at least one of the first AF evaluation value and the second AF evaluation value.

2. A photographing apparatus comprising:

a focus lens;

a lens drive unit which moves the focus lens in an optical axis direction;

an imaging unit which images an object at an interval of a predetermined time through the focus lens moving in the optical axis direction, and generates a plurality of pieces of image data;

a frequency component extraction unit which extracts a spatial frequency component from each piece of image data using a first filter and a second filter as high pass filters, a cutoff frequency of the first filter being higher than a cutoff frequency of the second filter;

an AF evaluation value acquisition unit which integrates the spatial frequency component extracted by the first filter to acquire a first AF evaluation value, and integrates the spatial frequency component extracted by the second filter to acquire a second AF evaluation value;

a variation calculation unit which calculates at least a first variation corresponding to first-order differentiation of the first AF evaluation value and a second variation corresponding to first-order differentiation of the second AF evaluation value at an interval of the predetermined time;

a moving speed control unit which controls a moving speed of the focus lens by the lens drive unit based on the first variation and the second variation;

a focal position detection unit which detects a focal position of the focus lens based on at least one of the first AF evaluation value and the second AF evaluation value;

a difference calculation unit which calculates a difference between the first AF evaluation value and the second AF evaluation value, the difference being calculated as $|E_1-E_2|$ where E_1 and E_2 are the first and second AF evaluation values respectively; and

a table storage unit which stores a plurality of tables defining at least a correspondence relationship between rates of increase or decrease of the first and second variations and the moving speed, the correspondence relationship being different according to the difference, wherein

the moving speed control unit selects a table corresponding to the difference calculated by the difference calculation unit from among the plurality of tables, and controls the moving speed of the focus lens by the lens drive unit based on the selected table.

3. A photographing apparatus comprising:

a focus lens;

a lens drive unit which moves the focus lens in an optical axis direction;

an imaging unit which images an object at an interval of a predetermined time through the focus lens moving in the optical axis direction, and generates a plurality of pieces of image data;

a frequency component extraction unit which extracts a spatial frequency component from each piece of image data using a first filter and a second filter as high pass filters, a cutoff frequency of the first filter being higher than a cutoff frequency of the second filter;

an AF evaluation value acquisition unit which integrates the spatial frequency component extracted by the first filter to acquire a first AF evaluation value, and integrates the spatial frequency component extracted by the second filter to acquire a second AF evaluation value;

a variation calculation unit which calculates at least a first variation corresponding to first-order differentiation of the first AF evaluation value and a second variation corresponding to first-order differentiation of the second AF evaluation value at an interval of the predetermined time;

a moving speed control unit which controls a moving speed of the focus lens by the lens drive unit based on the first variation and the second variation;

a focal position detection unit which detects a focal position of the focus lens based on at least one of the first AF evaluation value and the second AF evaluation value;

a difference calculation unit which calculates a difference between the first AF evaluation value and the second AF evaluation value; and

a table storage unit which stores a plurality of tables defining at least a correspondence relationship between rates of increase or decrease of the first and second variations and the moving speed, the correspondence relationship being different according to the difference, wherein

the moving speed control unit selects a table corresponding to the difference calculated by the difference calculation unit from among the plurality of tables, and controls the moving speed of the focus lens by the lens drive unit based on the selected table, wherein

the variation calculation unit calculates a third variation corresponding to second-order differentiation of the second AF evaluation value at an interval of the predetermined time in addition to the first and second variations, and

the table storage unit stores a plurality of tables in which the rates of increase or decrease of the first to third variations are associated with the moving speed.

4. A photographing apparatus comprising:

a focus lens;

a lens drive unit which moves the focus lens in an optical axis direction;

an imaging unit which images an object at an interval of a predetermined time through the focus lens moving in the optical axis direction, and generates a plurality of pieces of image data;

a frequency component extraction unit which extracts a spatial frequency component for each filter constituting a plurality of high pass filters using the plurality of high pass filters having different cutoff frequencies from each piece of image data;

an AF evaluation value acquisition unit which integrates the spatial frequency component extracted for each filter to acquire an AF evaluation value group composed of a plurality of AF evaluation values;

a variation calculation unit which calculates a variation of a value based on the AF evaluation value group at an interval of the predetermined time;

a moving speed control unit which controls a moving speed of the focus lens by the lens drive unit based on the variation;

a focal position detection unit which detects a focal position of the focus lens based on at least one AF evaluation value of the AF evaluation value group;

a luminance detection unit which detects a luminance of the object; and

a table storage unit which stores a plurality of tables defining a correspondence relationship between rates of increase or decrease of the variations and the moving speed, the correspondence relationship being different according to the luminance, wherein

the moving speed control unit selects a table corresponding to the luminance detected by the luminance detection unit from among the plurality of tables, and controls the moving speed of the focus lens by the lens drive unit based on the selected table.

5. A photographing apparatus comprising:

a focus lens;

a lens drive unit which moves the focus lens in an optical axis direction;

an imaging unit which images an object at an interval of a predetermined time through the focus lens moving in the optical axis direction, and generates a plurality of pieces of image data;

a frequency component extraction unit which extracts a spatial frequency component from each piece of image data using a first filter and a second filter as high pass filters, a cutoff frequency of the first filter being higher than a cutoff frequency of the second filter;

an AF evaluation value acquisition unit which integrates the spatial frequency component extracted by the first filter to acquire a first AF evaluation value, and integrates the spatial frequency component extracted by the second filter to acquire a second AF evaluation value;

an arithmetic unit which subtracts a value obtained by multiplying or adding a predetermined constant to the first AF evaluation value from the second AF evaluation value to calculate an arithmetic value;

a variation calculation unit which calculates a variation of the arithmetic value at an interval of the predetermined time;

a moving speed control unit which controls a moving speed of the focus lens by the lens drive unit based on the variation; and

a focal position detection unit which detects a focal position of the focus lens based on at least one of the first AF evaluation value and the second AF evaluation value, further comprising:

at least one pair of phase difference pixels provided in the imaging unit; and

a phase difference focal position detection unit which detects the focal position with the phase difference pixels, wherein

the moving speed control unit sets an initial speed for starting to move the focus lens to a predetermined value by the lens drive unit in the case where the distance between the position of the focus lens and the focal position detected by the phase difference focal position detection unit is equal to or greater than a predetermined value.

6. The photographing apparatus according claim **1**, wherein each of the first filter and the second filter is a digital

filter which subjects each piece of image data to a discrete cosine transformation process to extract the spatial frequency component.

* * * * *